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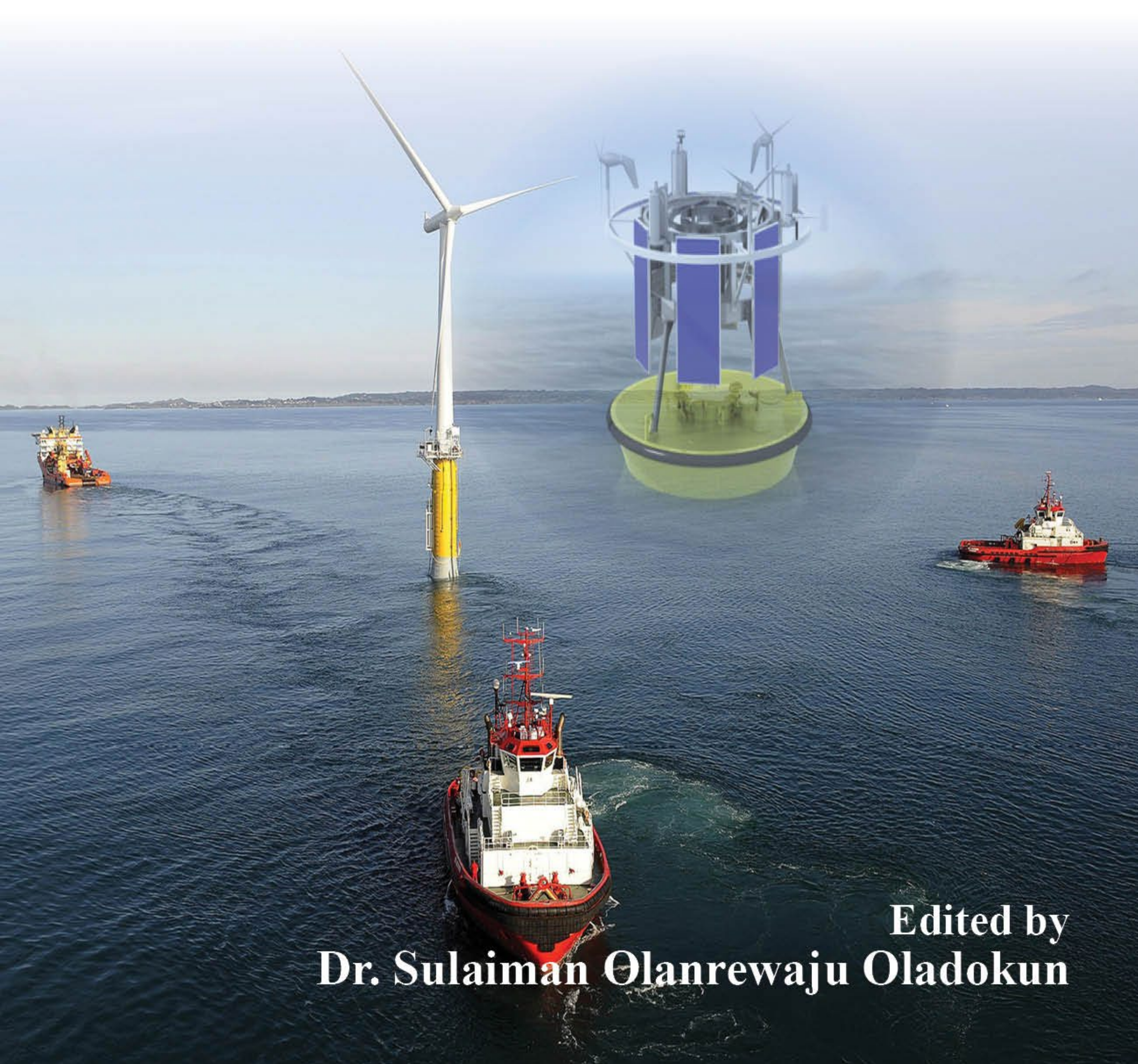
Marine safety Environmental Risk and Reliability Series



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Preface

The vastness of the ocean and its various processes that support life and earth remain a big challenge for humanity. Despite so much achievement in human civilization, logistic, to information technology to multimedia and sensor technology, the knowledge of water and ocean has left man with much more work to do on innovation front and new discovery. Modern day challenges are cluster of alternative energy, protection of the environment, ocean space exploration, sensing technology and material science. The book presents recent studies that have been carried out in maritime research and innovation front. Potential users of the books are library, societies, universities, research centers, professional bodies, government and NGO.

- Dr. Sulaiman Olanrewaju Oladokun

About Author

Dr.O.O.Sulaiman is Associate Professor of Ocean Engineering, and coordinator for Maritime Technology International program, University Malaysia Terengganu. His specialization is in Safety and Environmental risk and reliability for maritime and ocean systems, maritime and ocean energy and environment, sustainable maritime system design. He is chartered engineer with diverse academic and professional background. He has taught and mentor courses and research projects on contemporary issues in maritime and ocean engineering field. He has authored and co-authored a total of about more than 120 publications which include proceeding papers, journal papers, technical report and chapters in book, monograph, seminar papers and other types of academic publications. He has authored more than 60 peer review journals and 6 books. He has patented research work on marine green technology. He is chattered engineer registered under UK Engineering Council. He is the member of royal Institute of Naval Architecture (RINA) and Institute of Marine Engineering, Science and Technology (IMarEST), PIANC, IEEE, ASME.

Acknowledgement

A book that cover wide range of salient information on contemporary sustainable marine maritime technology and systems in coastal and ocean environment owe much appreciation to various individuals, equipment manufacturers and organizations. I am grateful for those who helped in different ways during the preparation of the book.

Introduction

The book will represent a master piece that provides information and guidance on future direction of marine technology and sustainability requirement. The book focuses on various contemporary issues that make its contents richer, more informative and beneficial to the wide number of readers in industry and academic sphere. This book provides the most recent information about proactive approach to sustainable development technology for readers about requirements of sustainable marine system. The book will be useful as followed:

- Reference material for academician, students, researcher, universities library, research institution as well as classroom subject.
- Networking, literature citation
- Useful information for maritime industry and organization Industry and regulatory institution.

Marine safety Environmental Risk and Reliability Series

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1. Safety and Environmental Risk and Reliability Model for Inland Waterway Collision Accident Frequency

Abstract

Marine vessel collisions cover the largest part of accidents scenario in waterways. Waterways accidents expose vessel owners and operators as well as the public to risk. They attract possibility of losses such as vessel cargo damage, injuries, loss of life, environmental damage and obstruction of water ways. Collision risk is a product of the probability of the physical event its occurrence as well as losses of various nature including economic losses. Environmental problem and need for system reliability call for innovative methods and tools to assess and analyze extreme operational, accidental and catastrophic scenarios as well as accounting for the human element and integrate these into a design environments part of design objectives. This paper discusses modeling of waterways collision risk frequency in waterways. The analysis consider mainly the waterways dimensions and other related variables of risk factors like operator skill, vessel characteristics, traffic characteristics, topographic, environmental difficulty of the transit and quality of operator's information in transit which are required for decision support related to efficient, reliable and sustainable waterways developments. The probability per year predicted is considered acceptable in maritime and offshore industry but for a channel using less number of expected traffic, it could be considered high. Providing safety facilities like traffic separation, vessel traffic management could restore maximize sustainable use of the channel.

Keywords: Collision; Environmental Prevention; Frequency; Inland Waterways; Risk; Reliability;

Introduction

Collision in waterways falls under high consequence incidents, collision data may be imperfect or inconstant, making it difficult to account for dynamic issues associated with vessels and waterways requirement. Accounting for these lapses necessitated need to base collision analysis on hybrid use of deterministic, probabilistic or simulation methods depending on the availability of a data.Developing sustainable Inland Water Transportation (IWT) requires transit risk analyses of waterways components and relationship between factors such as environmental conditions, vessel characteristics, operator's information about the waterway as well as the incidence of groundings and collisions using available data. Whatever information is available is useful for risk and reliability based decision work of accidents rate of occurrence, consequence and mitigation [1,2]. Risk and reliability based design entails the systematic integration of risk analysis in the design process targeting system risk prevention, reduction that meet high level goal and leave allowance for integrated components of the system including environment that will facilitate and support a holistic approach for reliable and sustainable waterways appropriate and require trade-offs and advance decision making leading to optimal design solutions.

Frequency estimation work on channel lead to fundamental sustainable model of transit risk that include factors such as traffic type and density, navigational aid configuration, channel design and waterway configuration and classification. For cases where there are insufficient historical record to support their inclusion, more comprehensive models of transit risk will have to rely on integral use of hybrid of deterministic, probabilistic, stochastic method whose result could further be simulated or employ expert judgment to optimize deduced result [3]. Risk based collision model are derivative for improvement of maritime accident data collection, preservation and limit acceptability using information relating to the following:

- Ports for entering incidents
- Wind speed and direction, visibility, water level, current speed and direction, etc.
- Eliminate/correct erroneous and duplicate entries (e.g. location information)
- Record data on actual draft and trim, presence and use of tugs, presence of pilots
- Types of cargo and vessel movements
- Report barge train movements as well as individual barges
- Improve temporal resolution (transits by day or hour)

This paper describes frequency analysis of risk based model, where accident frequency are determined and matched with waterway variables and parameter. The result hopes to contribute to decision support for development and regulation of inland water transportation.

Background

The study area is Langat River, 220 m long navigable inland water that has been under utilized. Personal communication and river cruise survey revealed that collision remain the main threat of the waterways despite less traffic in the waterways. This make the case to establish risk and reliability based model for collision aversion for sustainable development of the waterways a necessity. Data related to historical accidents, transits and environmental conditions were collected. Accident data are quite few, this is inherits to most water ways and that make probabilistic methods the best preliminary method to analyze the risk which can be optimized through expert rating and simulation methods as required Figure 1.

Barge and tug of capacity 5000T and 2000T are currently plying this waterway at draft of 9 and 15 m respectively. Collisions (including contact between two vessels and between a vessel and a fixed structure) causes of collision linked to navigation system failure, mechanical failure and vessel motion failure are considered in this work towards design of safe and reliable the river for transportation. Safety associated with small craft is not taken into account. Below is relevant information relating to channel, vessel and environment employed in the risk process. Lack of information about the distribution of transits during the year, the joint distribution of ship size, flag particular, environmental conditions become main derivative from probabilistic estimation.

Figure 1: Langat map.

In total risk management system of various methods is used according to result expectation and performance contribution. The study use Langat River to a case study to test the model, because it is a big River with big potential that is underutilized. The testing of the model on Langat could help decision support for its development and regulation in future. Table 1 shows some of advantage associated with use of the risk methods [2,4]. The model described is suitable for preventive safety reliability decision for new water way development. When it is safe the environment is preserved and protected.

Approach	Main Advantages	Main Disadvantages
Statistical method	Long been regarded as the only reliable sources.	Limitation with incident reports, difficulty in application to the future.
Comprehensive risk analysis	Rational, includes consequences.	Relies on accident data for benchmarking.
Stochastic method	Predict unfavourable conditions, inexpensive.	Targets known scenarios, limits choice of software/ programs, restricted to occurrence probability.
Computer simulation method	Target extreme condition.	Could left out certain information in real life.
Expert opinions	Long been used when limited by data.	Subjective.

Table 1: Methods for risk work.

Baseline Data's: Vessel movement, port call consists of two transits.

IN Langat River: one into and one out of the port. Safe transit data consider the same barge type and size for risk analysis are considered Table 2 and 3, Figure 2.

Channel Parameters	
Width	**Depth**
Maneuvering lane	Draught
Vessel Clearance	Trim
Bank suction	Squat
Wind effect	Exposureallowance
Current effect	Fresh water adjutment
Channel with bends	Maneuvering allowance
Navigationaids	Overdepth allowance
Pilot	depth transition
Tugs	Tidal alllowance

Table 2: River Langat tributary.

	Approach channel	
Design parameter	Straight	Bend
	98 m	120 m
	3-6 m	3-6 m
Side slope	10H:1V	10H:1V
Estuarine 135.7km	North (44.2km)	South (9.9km)

Table 3: River width and depth parameters.

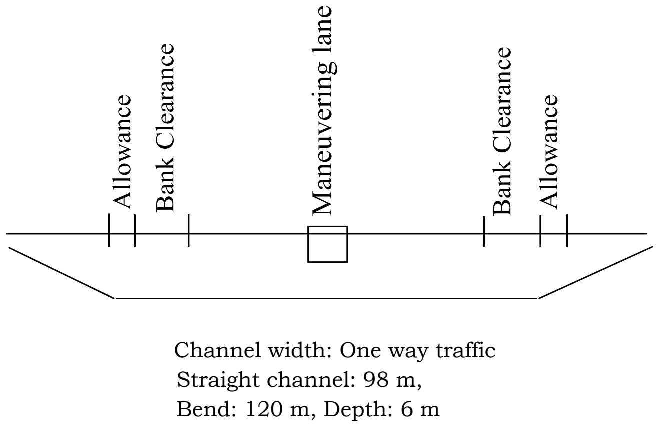


Figure 2: Channel width parameter.

Required radius of curvature at bends for 5000 DWT, Towed barge Length=Barge Length+Tug Length+Tow Line, R> (4-6) length of barge train (to meet the navigation requirement): PIANC, 2007. The main risk contributing factors can fall under the following:

Operator skill: There is no direct measure of this risk, inherently, highly skilled or seasoned operators and those with better local knowledge, may be expected to produce a lower risk of accidents. Flag ship or expert rating, port policy for entrance procedure could be used, this case frequency analysis relating to collision by barge flag or operator is considered

Vessel characteristics: Maneuverability capability of vessel could determine probability of accident, maneuverability data is difficult to acquire in waterways that has no Automatic Identification System (AIS) system in place. Therefore, analysis rely on derivative from vessel type and size, barge trains are, in general, likely to be less maneuverable than ships [5].

Traffic characteristics: Most wind and visibility information are hourly tracked through installed higher wind speed range which are likely from sensor located at the airport. There is potential visibility fluctuation resulting from this [3].

Topographic difficulty of the transit: The number of bent in the channel also adds to channel complexity which needs further consideration.

Environmental condition: This involves analysis of the effect of wind speed, visibility, and water level on accident risk. A transit characterized by unfavorable environmental conditions, such as high wind, poor visibility, or strong currents, may be expected to involve a greater risk of accidents than a transit through the same area under more favorable conditions.

Water Level: Accident due to tide are much linked to grounding, we assume that there is significant correlation between collision and grounding, Figure 3 shows the distribution of predicted and observed water level, if the distribution during groundings had a larger peak in the low water level, this could be due to increased risk of groundings or large (negative) errors in the tide forecasts used by vessel operators, this could be reduced through maximization of underkeel clearance against deep draft vessel [6].

Tide Forecast Error: Large forecast errors resulting in lower than forecast actual water levels. River complexity Figure 3 shows some of the model that is used to address various river complexities to manage safety and protect environment along Langat and it tributary. This model can be translated into benefit for reduction option.

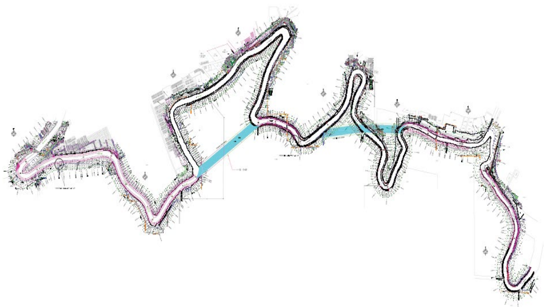


Figure 3: Channel straightening and alignment.

Barge parameter	2000 tons	5000 tons
Length (m)	67.3	76.2
Beam (m)	18.3	21.3
Depth (m)	3.7	4.9
Draft (m)	2.9	4.0

Table 4: Vessel requirement: barge parameter.

Tugs parameter	2000 tons	5000 tons
Length (m)	23.8	23.8
Beam (m)	7.8	7.8
Depth (m)	3.5	3.5
Draft (m)	2.8	2.8
Horse Power (hp)	1200	1200

Table 5: Vessel requirement: tug parameter.

Table 4 and 5 shows the environmental parameters considered in the risk process.

Quality of operator's information: quality of operator information about environmental conditions, information about currents, tide levels and winds can help in the risk process.

Uncertainty in Surveys/Charts: it is better to use hydrostat for interpolation of the locations of the accidents as plotted on a chart. Thus that comes with bargage of point error distribution for depth survey.

Real-time Environmental Information: for this it is important to use caution when comparing accident rates across ports and over time because of differences in reporting criteria. However the annual accident data collected is good for preliminary analysis using probabilistic method can give information about possible temporal factor changes [7] Figure 4, 5 and 6.

Frequency of accident and geographical distribution of transit through open and water approach survey could also help in analysis of uncertainty Table 6.

Model	Tool	
Rainfall-Runoff model	NAM	Contribution of catchments runoff to Langat river
One-Dimensional River model	MIKE11	Establish baseline condition of tide, salinity, and flood level of the Langat river. Assess the impacts of navigational improvement plan
Two-Dimensional Curvilinear Grid Model	MIKE21 C	assess the impacts of navigational, improvement plan on erosion/ deposition, pattern of the Langat river
Two-Dimensional Rectangular Grid Nested Model	MIKE21	Establish baseline condition of tide, wave, erosion/deposition pattern for Langat river mouth assess the impacts of proposed navigation improvement plan

Table 6: River Models.

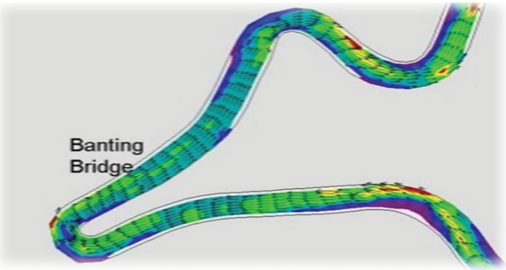


Figure 4: Tide movement and current EB, Green to red: low to high speed.

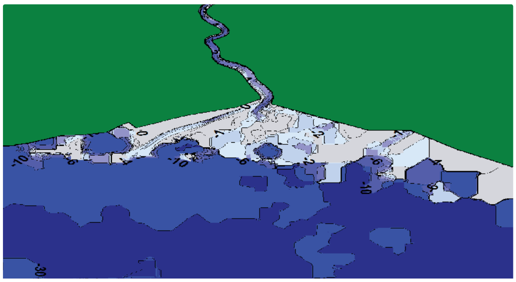


Figure 5: Water level Mean, water level = 40cm seasonal variation, Existing coastal environmental current.

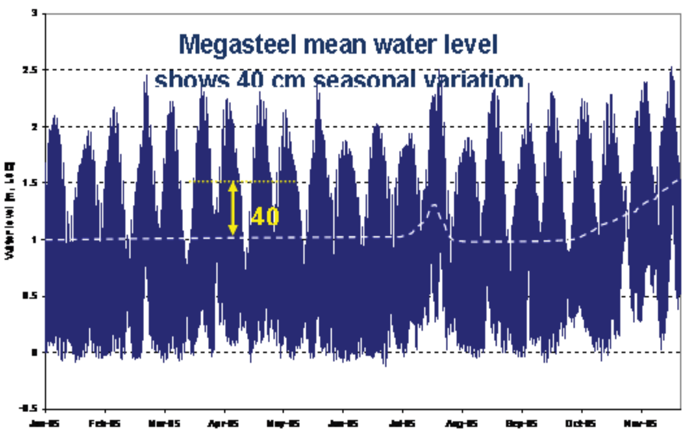


Figure 6: Coastal current, Avg. Speed in Spring tide 0.4-1.2 m/s, avg. Speed in Neap 0.2 - 1.0 m/s.

Data collection limitation: Limitations in data collection poised hybrid combinatory use of historical, first principle or deterministic and stochastic analysis, future data collection effort can open opportunity for improvement in validation analysis as well as understanding of accident risk. In this case the data is good enough data to model a predictive and state space analysis model of frequency of occurrence in the channel. Major data problems are as follows:

Vessel casualty data: Inherent problem with causality data have missing entries, duplicate entries, and inaccuracies. Lack of recording of location of accidents in theory expected to be to the tenths of minute's latitude/longitude for accuracy. In reality rarely latitude/longitude information is rarely given, leading to erroneous location information. Data limitation are lack draft or trim data of vessels at the time the accident happen, actual water depth at the time of the accident from the environmental data, lack of quantification in the use of tugs and present of pilot [8].

Environmental data: Limitations are associated with potential change in real-time oceanographic data systems. Wind and visibility are general to each port area, and measured at an airport location that does not necessarily reflect conditions on the water. No historical information on currents, lack of consistency on wind and visibility, and water level and current conditions.

Port-Specific data: information about safe transits counts categorization by flag, vessel type, vessel size, with tug escort and piloting information, taken at hourly by authority.

Surveys and chart data: it is important to compare conventional cartographic uncertainty and with new technology to cover additional uncertainties.

Safety and enviromental risk for IWT: Risk and reliability based model aim to develop innovative methods and tools to assess operational, accidental and catastrophic scenarios. It requires accounting for the human element and integrates them as required into the design environment. Risk based design entails the systematic integration of risk analysis in the design process. It target safety and environment risk prevention and reduction as a design objective. To pursue this activity effectively, an integrated design environment to facilitate and support a holistic risk approach to ship and channel design is needed. Total risk approaches enable appropriate trade off for advanced sustainable decision making. Water ways accident falls under scenario of collision, fire and explosion, flooding, grounding.

- Loss of propulsion
- Loss of navigation system
- Loss of mooring function and
- Loss of other accident from the ship or water ways

Risk based design entails the systematic risk analysis in the design process targeting risk preventive reduction. It facilitates support for total risk approach to ship and waterways design. Integrated risk based system design requires the availability of tools to predict the safety, performance and system components as well as integration and hybridisation of safety element and system lifecycle phases. Therefore, it becomes imperative to develop, refine, verify, validate reliable model through effective methods and tools. The risk process begins with definition of risk which stands for the measure of the frequency and severity of consequence of an unwanted event (damage, energy, oil spill). Frequency at which potential undesirable event occurs is expressed as events per unit time, often per year. The frequency can be determined from historical data. However, it is quite inherent that event that don't happen often attract severe consequence and such event are better analyzed through risk based and reliability model. Figure 3 shows main components of risk based design for IWT. Risk is defined as product of probability of event occurrence and its consequence.

Risk (R) = Probability (P) X Consequence (C) (1)

Incidents are unwanted events that may or may not result to accidents. Necessary measures should be taken according to magnitude of event and required speed of response should be given. Accidents are unwanted events that have either immediate or delayed consequences. Immediate consequences variables include injuries, loss of life, property damage, and persons in peril. Point form consequences variables could result to further loss of life, environmental damage and financial costs. The earlier stage of the process involves finding the cause of risk, level of impact, destination and putting a barrier by all mean in the pathway. Risk work process targets the following:

Cause of risk and risk assessment, this involve system description, identifying the risk associated with the system, assessing them and organising them in degree or matrix. IWT risk can be as a result of the following:

- Root cause.
- Immediate cause
- Situation causal factor.
- Organization causal factor

Risk analysis and reduction process, this involve analytic work through deterministic and probabilistic method that strengthen can reliability in system. Reduction process that targets initial risk reduction at design stage, risk reduction after design in operation and separate analysis for residual risk for uncertainty as well as human reliability factor.

Uncertainty risk in complex systems can have its roots in a number of factors ranging from performance, new technology usage, human error as well as organizational cultures. They may support risk taking, or fail to sufficiently encourage risk aversion. To deal with difficulties of uncertainty risk migration in marine system dynamic, risk analysis models can be used to capture the system complex issues, as well as the patterns of risk migration. Historical analyses of system performance are important to establish system performance bench marks that can identify patterns of triggering events, this may require long periods of time to develop and detect. Assessments of the role of human and organizational error and its impact on levels of risk in the system are critical in distributed, large scale dynamic systems like IWT couple with associated limited physical oversight. Effective risk assessments and analysis required three elements highlighted in the relation below.

Risk modeling = Framework + Models + Process (2)

Reliability based verification and validation of system in risk analysis should be followed with creation of database and identification of novel technologies required for implementation of sustainable system.

Risk framework: Risk framework provides system description, risk identification, criticality, ranking, impact, possible mitigation and high level objective to provide system with what will make it reliable. The framework development involves risk identification which requires developing understanding the manner in which accidents, their initiating events and their consequences occur. This includes assessment of representation of system and all linkage associated risk related to system functionality and regulatory impact (Figure 7)

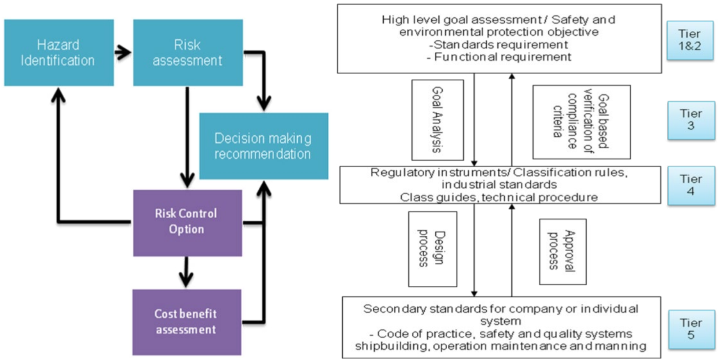


Figure 7: IMO Risk framework.

Risk framework should be developed to provide effective and sound risk assessment and analysis. The process requires accuracy, balance and information that meet high scientific standards of measurement. The information should meet requirement to get the science right and getting the right science. The process requires targeting interest of stake holder including members of the port and water way community, public officials, regulators and scientists. Transparency and community participation helps ask the right questions of the science and remain important input to the risk process, it help checks the plausibility of assumptions and ensures that synthesis is both balanced and informative. Employment of quantitative analysis with required insertion of scientific and natural requirements provide analytical process to estimate risk levels, and evaluating whether various measures for risk are reduction are effective.

Safety and Environmental Risk and Reliability Model (SERM)

There is various risk and reliability tools available for risk based methods that fall under quantitative and qualitative analysis. Choice of best methods for reliability objective depends on data availability, system type and purpose. However employment of hybrid of methods of selected tool can always give the best of what is expect of system reliability and reduced risk. Figure 8 shows generic risk model flow chart.

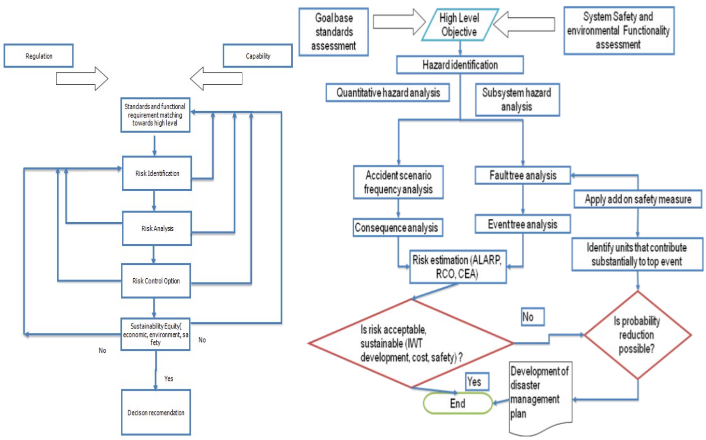


Figure 8: Risk and Reliability model flow charts

SERM process: SERM intend to address risks over the entire life of the complex system like IWT system where the risks are high or the potential for risk reduction is greatest.

SERM address quantitatively, accident frequency and consequence of IWT. Other risk and reliability components include human reliability assessment which is recommended to be carried out separately as part of integrated risk process. Other water ways and vessel requirement factors that are considered in SERM model are:

- Construction
- Towing operations and abandonment of ship
- Installation, hook-up and commissioning
- Development and major modifications

Integrated risk based method combined various technique as required in a process. Table 7 shows available risk based design for techniques. This can be applied for each level of risk. Each level can be complimented by applying causal analysis (system linkage), expert analysis (expert rating), and organizational analysis (Community participation) in the risk process. Figure 7 shows stakes holder that should be considered in risk process. From Figure 8, the method use is risk analysis that involves frequency analysis where the system is modelled with hybrid of deterministic, probabilistic and stochastic process. Technically, the process of risk and reliability study involves the following four areas:

System definition of high goal objective: This requires defining the waterways by capturing gap between system functionality and standards. The scope of work for safely and environment risk and reliability analysis should define the boundaries for the study. Identifying which activities are included and which are excluded, and which phases of the system's life are to deal with.

Qualitative hazard identification and assessment: It involves hazard identification through qualitative review and assessment of possible accidents that may occur, based on previous accident as well as experience or judgment of system users where necessary. Though, using selective and appropriate technique depends on the range, magnitude of hazards and indicates appropriate mitigation measures.

Quantitative hazard frequency and consequence analysis: once the hazards have been identified and assessed qualitatively. Frequency analysis involves estimation of how likely it is for the accidents to occur. The frequencies are usually obtained from analysis of previous accident experience, or by some form of analytic modelling employed in this thesis. In parallel with the frequency analysis and consequence modelling evaluates the resulting effects of the accidents, their impact on personnel, equipment and structures, the environment or business.

Risk acceptability, sustainability and evaluation: Is the yardsticks to indicate whether the risks are acceptable, in order to make some other judgment about their significance. This begins by introducing non technical issues of risk acceptability and decision making. In order to make the risks acceptable. The benefits from these measures can be evaluated by iterative process of the risk analysis. The economic costs of the measures can be compared with their risk benefits using cost benefit analysis leading to results of risk based analysis. This input necessities to the design or ongoing safety management of the installation, to meet goal and objectives of the study.

Process	Suitable techniques
HAZID	HAZOP, What if analysis, FMEA, FMECA
Risk analysis	Frequency, consequence, FTA, ETA
Risk evaluation	Influence diagram, decision analysis
Risk control option	Regulatory, economic, environmental,function elements matching and iteration
Cost benefit analysis	ICAF, Net Benefit
Human reliability	Simulation/ Probabilistic
Uncertainty	Simulation/probabilistic
Risk monitoring	Simulation/ probabilistic

Table 7: Risk based design techniques.

The process of risk work can further be broken down into the following elements:

- Definition and problem identification
- Hazard and consequence identification
- Analysing the likelihood's of occurrence
- Analyzing consequences
- Evaluation of uncertainty
- Risk Control Option (RCO) and Risk Control Measure (RCM)
- Sustainability of (cost safety, environment, injury, fatality, damage to structure, environment) and risk acceptability criteria
- Reliability based model verification and validation: statistical software, triangulation, iteration.

Recommendation for implementation: Implement, establishing performance standards to verify that the arrangements are working satisfactorily and continuous monitoring, reviewing and auditing the arrangements

Employment of these benefit provide a rational. Formal environmental protection structure and process for decision support guidance and monitoring about safety issues. The scope of sustainable risk based design under consideration involves stochastic, analytic and predictive process work leading to avoidance the harms in water ways. Figure 8 shows block diagram of SERM components for IWT. Safety and Environmental Risk and Reliability Model (SERM) for IWT required having clear definition of the following issues: Figure 9

- Personnel, attendance
- Identify activities
- Vessel accidents including passing vessel accident, crossing , random
- Vessel location and waterway geography on station and in transit to shore.
- Impairment of safety functions through determination of likelihood of loss of key safety functions lifeboats, propulsion temporary refuge being made ineffectiveness by an accident.
- Risk of fatalities, hazard or loss of life through measure of harm to people and sickness.
- Property damage through estimation of the cost of clean-up and property replacement.
- Business interruption through estimation of cost of delays in production.
- Environmental pollution may be measured as quantities of oil spilled onto the shore, or as likelihood's of defined categories of environmental impact or damage to infrastructures.

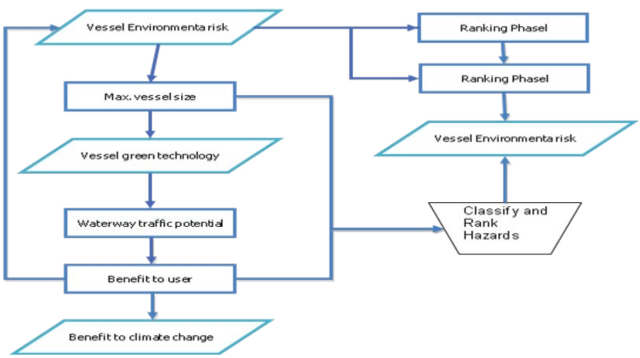


Figure 9: IWT safety and environmentalmodel components block diagram.

Allowance should be made to introduce new issue defining the boundary in the port from time to time. The choice of appropriate types of risk tool required for the model depend on the objectives, criteria and parameter that are to be used. Many offshore risk based design model consider loss of life or impairment of safety functions. There is also much focus on comprehensive evaluation of acceptability and cost benefit that address all the risk components. Figure 9 shows the risk and reliability model combined process diagram. The analysis is a purely technical risk analysis. When the frequencies and consequences of each modelled event have been estimated, they can be combined to form measures of overall risk including damage, loss of life or propulsion, oil spill. Various forms of risk presentation may be used. Risk to life is often expressed in two complementary forms. The risk experienced by an individual person and societal risk. The risk experienced by the whole group of people exposed to the hazard (damage or oil spill).

Accident and incident are required to be prevented not to happen at all. The consequence of no safety is a result of compromise to safety leading to unforget table loses and environmental catastrophic. Past engineering work has involved dealing with accident issues in reactive manner. System failure and unbearable environmental problem call for new proactive ways that account for equity requirement for human, technology and environment interaction. The whole risk assessment and analysis process starts with system description, functionality and regulatory determination and this is followed by analysis of:

- Fact gathering for understanding of contribution factor
- Fact analysis of check consistency of accident history
- Conclusion drawing about causation and contributing factor
- Countermeasure and recommendation for prevention of accident

Most risk based methods define risk as:

Risk = Probability (Pa) x Consequence (Ca) (3)

or in a more elaborate expression risk can be defined as:

Risk = Threatx Vulnerability x {direct (short-term) consequences + (broad) Consequences} (4)

In risk analysis, serenity and probability of adverse consequence hazard are deal with through systematic process that quantitatively measure, perceive risk and value of system using input from all concerned waterway users and experts.

Risk can also be expressed as:

Risk = Hazard x Exposure (5)

Where hazard is anything that can cause harm (e.g. chemicals, electricity, Natural disasters), while exposure is an estimate on probability that certain toxicity will be realized. Severity may be measured by No. of people affected, monetary loss, equipment downtime and area affected by nature of credible accident. Risk management is the evaluation of alternative risk reduction measures and the implementation of those that appear cost effective where:

Zero discharge or negative damage = Zero risk (6)

The risk and reliability model subsystem in this thesis focus on the following identified four risks assessment and analysis application areas that cover hybrid use of technique ranging from qualitative to qualitative analysis:

- Failure Modes Identification Qualitative Approaches
- Index Prioritisation Approaches
- Portfolio Risk Assessment Approaches and
- Detailed Quantitative Risk Assessment Approaches.

Collision and risk modelling

Collision in waterways is considered low frequency and high consequence events that have associative uncertainty characteristics/component of dynamic and complex physical system. This makes risk and reliability analysis the modest methods to deal with uncertainties that comes with complex systems. Employment of hybrid deterministic, probabilistic and stochastic method can help break the barriers associated with transit numbers data and other limitation. Conventionally, risk analysis work often deal with accident occurrence, while the consequence is rarely investigated, addressing frequency and consequence analyze can give clear cuts for reliable objectives. Risk and reliability based design can be model by conducting the following analysis that includes the following process [9,10]:

- Risk identification
- Risk analyses
- Damage estimation
- Priotization of risk level
- Mitigation

Repriotization of exposure category: mitigate risk or consequence of events that meet ALARP principle. Reassess high risk events for monitoring and control plans.

- Recommendation
- Implementation
- Continuous monitoring
- Improvement.

Collision is likely to be caused by the following factors shown in Figure 10 derived from fault three analyses from RELEX software. The relex software is based on fault three analysis where consequence of causal events are add up through logic gate to give minimum cut set probability that trigger the event. It is more effective for subsystem analysis.

P (collision) = P (propulsion failure) + P (loss of navigation failure) + P (Loss of vessel motion) (7)

There is also causes are mostly as a result of causes from external sources like small craft are cause of cause, cause from other uncertainty including human error may attract separate subsystem analysis.

Collision data: Collision data are drawn from relevant marine administrator; there is expectation that most data gaps can be covered by the probability estimations. The Langat River work model risk through systemic analysis procedures for sustainable inland waterways transportation. It determine the probability of failure or occurrence, risk ranking, damage estimation, high risk to life safety, cost benefit analyze, sustainability and acceptability criteria [7,11]. The study analyze causal accidental relating to navigational, mechanical failure and human error and ignored those identified as intentional for barge and tugs of 5000T and 2000T having respective drift of draft greater than 9 to 15 m. Table 8 shows some of the annual traffic summary, collision and the consequences on Langat. Seasonal trends can be stochastically modelled from probabilistic result, environmental condition and traffic volume fluctuation is also considered negligible. For visibility, navigation is considered to be more risky at night than day time, the analysis follow generic assumption for evenly safe distribution evenly during day and night Figure 10 and 11.

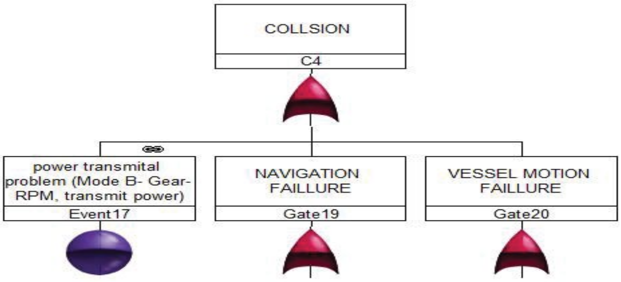


Figure 10: Collision contributing factors (RELEX).

Figure 11: Tugs puling barge inLangat.

Absence of data should not be used as an excuse for not taking an advantage of the added knowledge that risk assessment can provide on complex systems [12]. Approximation of the risks associated with the system can provide a definition of data requirements. The treatment of uncertainty in the analysis is important, and the limitations of the analysis must be understood. However, data management system and better approach can always accommodate little data or no data. Table 8 shown models that have been used design of system based on risks in marine industry.

Model	Application	Drawback
Brown et al., [12]	Environmental Performance of Tankers	
Sirkar et al., [12]	Consequences of collisions and groundings	Difficulties on quantifying consequence metrics
Brown and Amrozowicz	Hybrid use of risk assessment, probabilistic simulation and a spill consequence assessment model	Oil spill assessment limited to use of fault tree
Sirkar et al., [12]	Monte Carlo technique to estimate damage AND spill cost analysis for environmental damage	Lack of cost data
IMO 13F 1995	Pollution prevention index from probability distributions damage and oil spill.	Lack [12]. rational
Research Council Committee	Alternative rational approach to measuring impact of oil spills	Lack employment of stochastic probabilistic methods
Prince William Sound, Alaska, (PWS)	The most complete risk assessment	Lack of logical risk assessment framework (NRC)
Volpe National Transportation Center	Accident probabilities using statistics and expert opinion.	Lack employment of stochastic methods
Puget Sound Area (USCG (1999).	Simulation or on expert opinion for cost benefit analysis	Clean up cost and environmental damage omission

Table 8: Previous risk work.

IMO and Sirkar et al., [12] methods lack assessment of the likelihood of the event, likewise other model lack employment of stochastic method whose result could cover uncertainties associated with dynamic components of channel and ship failure from causal factors like navigational equipment, training and traffic control [11]. Therefore, combination of stochastic, statistical and reliability method based on combination of probabilistic, goal based, formal safety assessment, deterministic methods and fuzzy method using historical data's of waterways, vessel environmental, first principle deterministic and traffic data can deliver best outcome for predictive, sustainable, efficient and reliable model for complex and dynamic system like inland water transportation. The general hypothesis behind assessing physical risk model is that the probability of an accident on a particular transit depends on a set of risk variables require for analysis of prospective reliable design. Figure 7, 8 and 9 show traffic data utilized in the model. Most of the method above used historical data, the novel method in this paper used limited data of traffic used to model the physics of the system, the transfer function and stochastically project accident frequency. The projection is generic and can be used for any waterways and it consider random collision not which is not considered by previous model Table 9,10 and 11.

Jetty	3 nos.
Daily	9 times.
Weekly	63 times.
Monthly	252 times.
Annually	3024 times.

Table 9: Tug boat & vessel activities along river for 2008.

Total number of barge	Time	Traffic
12	Every day (24 hrs.)	
6	(every 4 hrs)	Incoming
6	(every 4 hrs)	outgoing

Table 10: Vessel traffic.

ALL Speed	2 – 3 knots
Traffic	ALL single way traffic
Lay -bys	Proposed four locations for Lay-bys

Table 11: Common to traffic.

Traffic Frequency Estimation Modelling: Traffic density of meeting ship Figure 12

Traffic density of meeting ship: $\rho = \frac{Nm}{v.\tau.W}$ Ships/m^2 (8)

Where,

Nm is number of ships frequenting the channel

v is speed of the ship, T= time of traffic activities per annum

W is width of the channel.

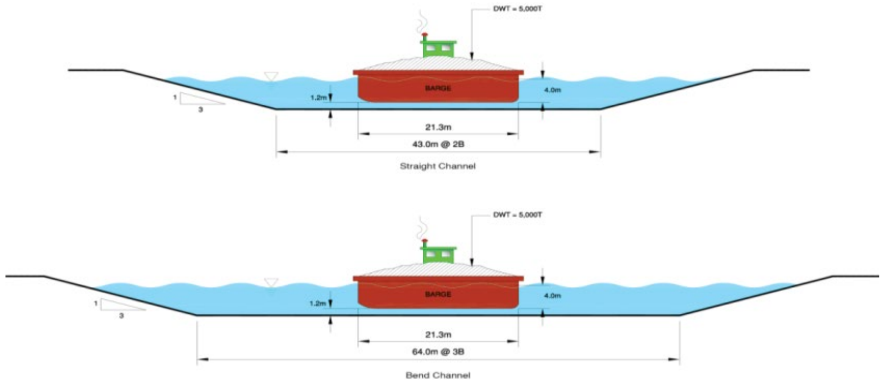


Figure 12: 5000 barge data and Langat waterway.

Analysis of Present Situation

Traffic situation: Below are representations of various collision situations for head on, over taking and crossing (angle) collision scenario (Figure 13).

Where: B1 = mean beam of meeting ship (m), V1 = mean speed of meeting ship (knots), B2 = beam of subject ship (m), V2 = speed of subject ship (knots), Nm = arrival frequency of meeting ships (ship/time), D= relative sailing distance.

Expected number of collision Ni= 9.6.B. ρ_s = 1/passage Eq. 2

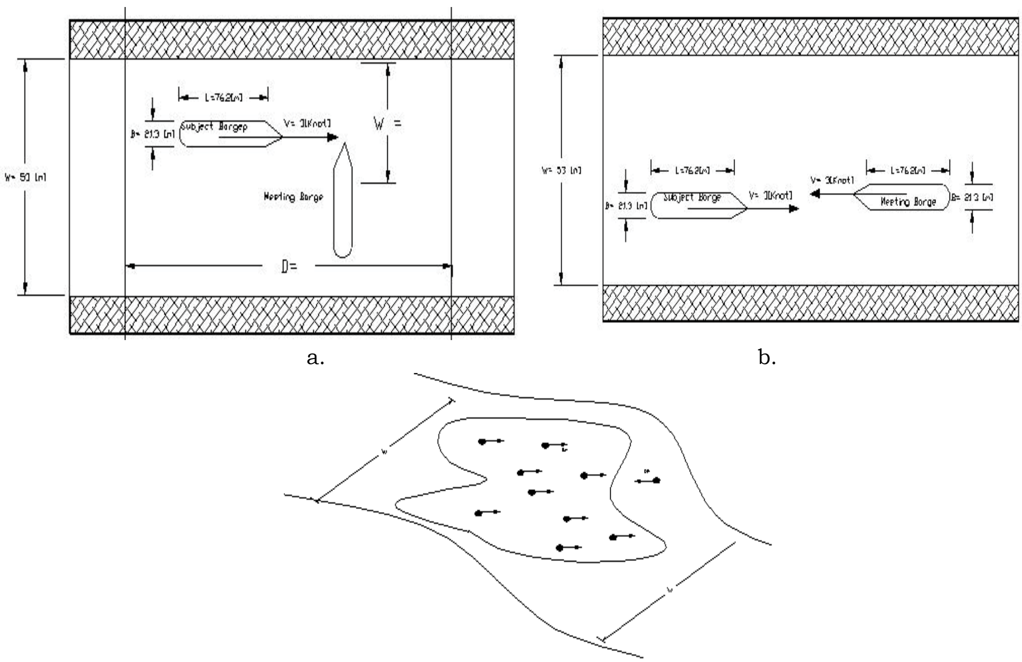


Figure 13: Collision situations, a. overtaking, b. passing cases, c. Random.

Table 12 shown, relevant data from previous analysis

Expression	Head – on	Overtaking	Random
Basic	4 x B X D X	$\frac{B_1+B_2}{W}.\frac{V_1+V_2}{V_1.V_2}.D..N_M$	$Ni=\frac{N}{\tau.V}\frac{4}{(\Pi * L+2*B)}$
Standardised		$\frac{B_1+B_2}{W}.\frac{V_1+V_2}{V_1.V_2}.D..N_M$	$\rho_n.B$
Relative	1	1	2.4

Table 12: Expression for collision situation.

Approximations:

L=6B, D=W, $N_i = P_i$ (9)

Necessary period for ship to pass the fairway T=D/v = 3000/3 = 1000 sec (10)

Table 13 and 14 shows primary data for approximation

	μ_C (failure per nautical mile or hour)	Pc (failure per passage or encounter
Head on	2.5 x10^{-5}	2.7.x10^{-5}
Overtaking	1.5 x10^{-5}	1.4.x10^{-5}
Crossing	1.5 x10^{-5}	1.3 .x10^{-5}

Table 13: Failure per nautical mile and failure per passage for collision situation [13].

Therefore average Pc and $\mu_c = 2.5\times10?^{(-5)}$ for random (11)

Probability of loosing navigation control within the fairway

Pc = μ_c.T failure/passage (12)

Fairway	μc (failure per nautical mile or hour)	Pc (failure per passage or encounter
UK	2.5 x10^{-5}	1.x10^{-4}
US	1.5 x10^{-5}	1.4.x10^{-5}
Japan	3.0 x10^{-5}	1.3.x10^{-5}

Table 14: Failure per nautical mile and failure per passage for different waterways [14].

Probability of collision Pa= (Pi. Pc collision/passage) (13)

Collision per annual (Na) = Pa. N_m Collision per year (14)

In the frequency analysis, the annual frequency of each failure case is estimated. Separate frequencies are estimated for each operating phase as required. In modelling the development, consequences and impact of the events, each failure case is split into various possible outcomes. The outcomes are the end events on an event tree or chain of event trees. Each outcome probability is estimated by combining the probabilities for appropriate branches of the event tree.

The outcome frequency (Fo) is then:

$$F_o = F_e \prod P_b \quad (15)$$

Where, F_e is failure frequency, P_b probability of one segment, Not all possible outcomes are modelled. Representative scenarios are selected for modelling, and the scenario frequency is taken as:

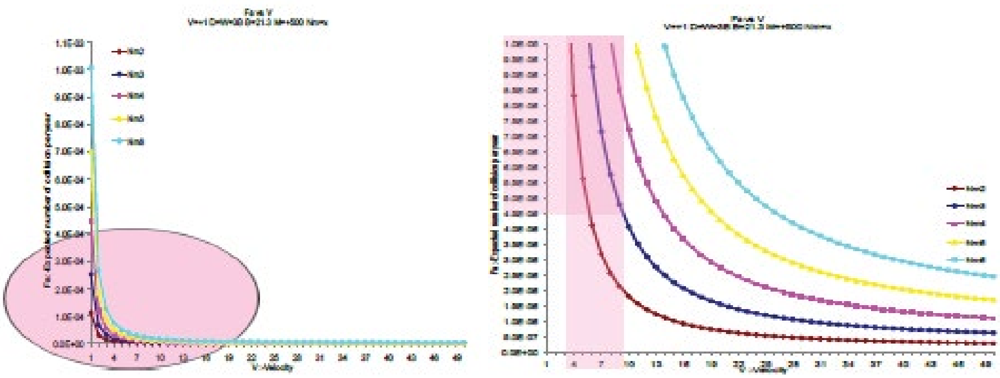
$$F_s = \sum_{outcomes} F_o \quad (16)$$

Failure per nautical mile and failure per passage can be selected from previous representative work. Necessary period for ship to pass the fairway T=D/v = 3000/3 = 1000 sec. The result of accident frequency (Fa) can be compare with acceptability criteria for maritime industry. If it is two high the system could be recommended to implement TSS. If the result is high TSS can be model to see possible reduction due to its implementation. Table 15 shows frequency risk acceptability criteria for maritime and offshore industry.

Frequency classes	Quantification
Very unlikely	once per 1000 year or more likely
Remote	once per 100- 1000 year
Occasional	once per 10- 100 year
Probable	once per 1- 10 years
Frequent	more often than once per year

Table 15: Frequency acceptability criteria.

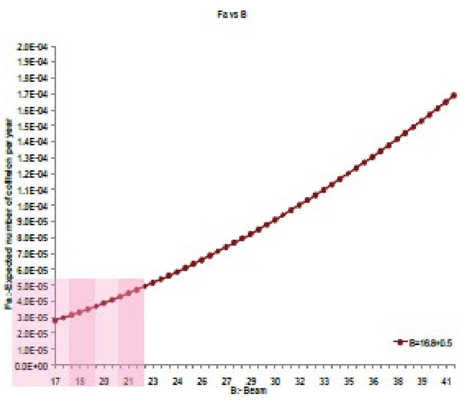
Frequency analysis result: This result indicates that the collision in Langat is not risk on ALARP graph. Accident per year of 5.3E-5 is observed for current 3 number of vessel operating at speed of 3 knot. But physical observation revealed that there is significant and exception increase in collision that needs to be address for a channel with less traffic density. It is also observed from the plot of frequency Vs speed that when traffic density is changing traffic density of 5 and 6 and speed up to 5 considered to be cause high risk of accident frequency in the waterway (Figure 14).



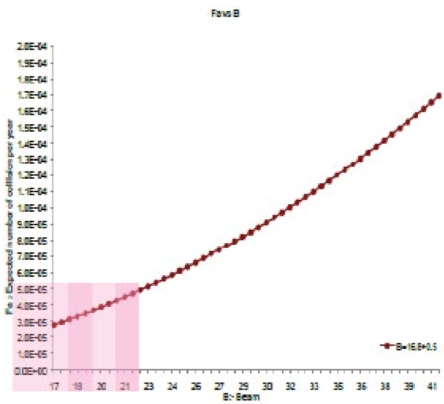
(a) (b)

Figure 14: Accident frequency Vs at changing number of ship.

Figure 15 a shows accident frequency at changing width and beam of the channel. Risk is acceptable for accident per 10,000 year, if proposed maintenance of channel improvement plan is implemented. The maximum speed is round 10 knot for width of 64 m and probability of 1/1000 years, other speed above this are intolerable. As width of the channel decrease there is higher risk -> Accident frequency probability increase. The maximum width considered for Langat River is 64 this width is considered too small and risky for the channel for accident per 1000 years. Different speed should be advised to ship for such situation. Width of channel can change as a result of erosion. Increasing channel width to 250m could allow speed of 20 knot at acceptable Fa (Na) of 1x10E-4. Ship operating at Langat at 3 knot at River Langat, is considered not high risk for accident per 100, 000 years. The regression equation for the trend is represented by y is 2E-08x + 1E-05 @ R^2 is 1. Similar trend is observe for Figure 15b, the beam and width are related according to PIANC W=3B AND L=6B. Table 16 shows regression equations for the frequency analysis



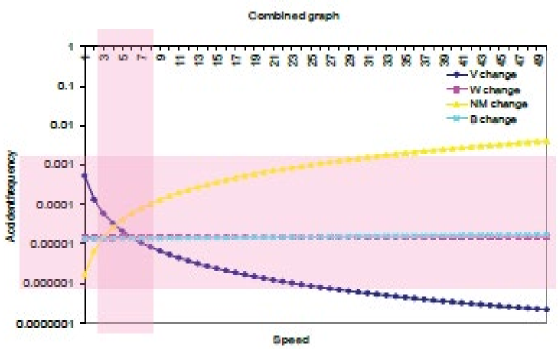
(a)



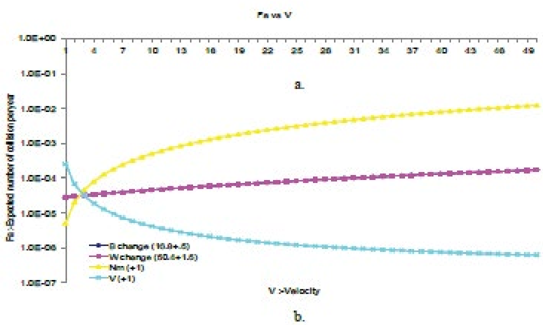
(b)

Figure 15: (a) (b): Accident frequency Vs beam and width of the channel.

Figure 16 a and b shows cross ploting of the channel variable, both plots are the same, the defence is that Figure 12b is logged because of large number shows the risk level for all channel parameters variables (speed, width, number of ships and beam of ship). It is observed that the maximum of ship can up to 4 at the point where speed and Number of ship curves meet provided all channel and vessel safety parameters are in place.



(a)



(b)

Figure 16: (a) (b): cross plotting of channel variables (speed, width, number of ships, and beam of ship).

Figure 17 Table 16 shows number of expected collision (Ne = Ni) vs collision impact angle, since high impact is associated with high speed, the result show that high impact is likely to occur at angle between 105-115 degree at for al speed at Ni = Ne = 2.9E-5.

Frequency model				
Fa	@Nm changing Speed	$y = 2E\text{-}05e^{-0.11x}$	$R^2 = 0.826$	Exponential
Fa	@V	$y = 2E\text{-}05e^{-0.11x}R^2 =$ 0.826	$R^2 = 1$	Square
Fa	W	y = 2E-08x + 1E-05	$R^2 = 1$	Square
Fa	B	y = 9E-07x + 0.000	$R^2 = 0.999$	Linear

Table 16: Regression equations for the frequency analysis.

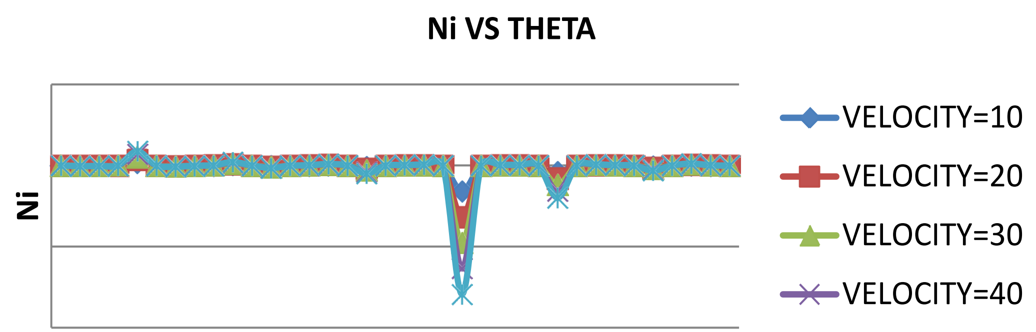


Figure 17: Impact Vs Angle, Highest impact expected at v= 50 and collision angle between 105-115l.

Uncertainty and system complexity analysis

Subsystem level analysis: For total risk work the following analysis could perform separately as part of subsystem risk level analysis:

- Power transmission
- navigation
- vessel motion and
- human reliability

Subsystem level analysis can be facilitated by using frequency calculation through. Fault Tree Analysis (FTA) modelling involve top down differentiation of event to branches of member that cause them or participated in the causal chain action and reaction. While consequence calculation can be done by using Event Tree Analysis (ETA), where probability is assigned to causal factor leading to certain event in the event tree structure.

Channel complexity analysis: Channel complexity that could be addressed in the risk and reliability work is visibility weather, squat, bridge, river bent and human reliability. Figure 18 show channel complexity for Langat. Poor visibility and the number of bend may increase in the risk of and collisions. A model extracted from Dover water way studies concluded with the following:

Fog Collision Risk Index (FCRI) = $P_1 + VI_1 + P_2 + VI_2 + P_3 + VI_3$ (17)

Where: P_K = Probability of collision per million encounters, VI_K = Fraction of time that the visibility is in the range k, K = Visibility range: clear (>4km), Mist/Fog (200 m-4 km), Tick/dense (less than 200 m).

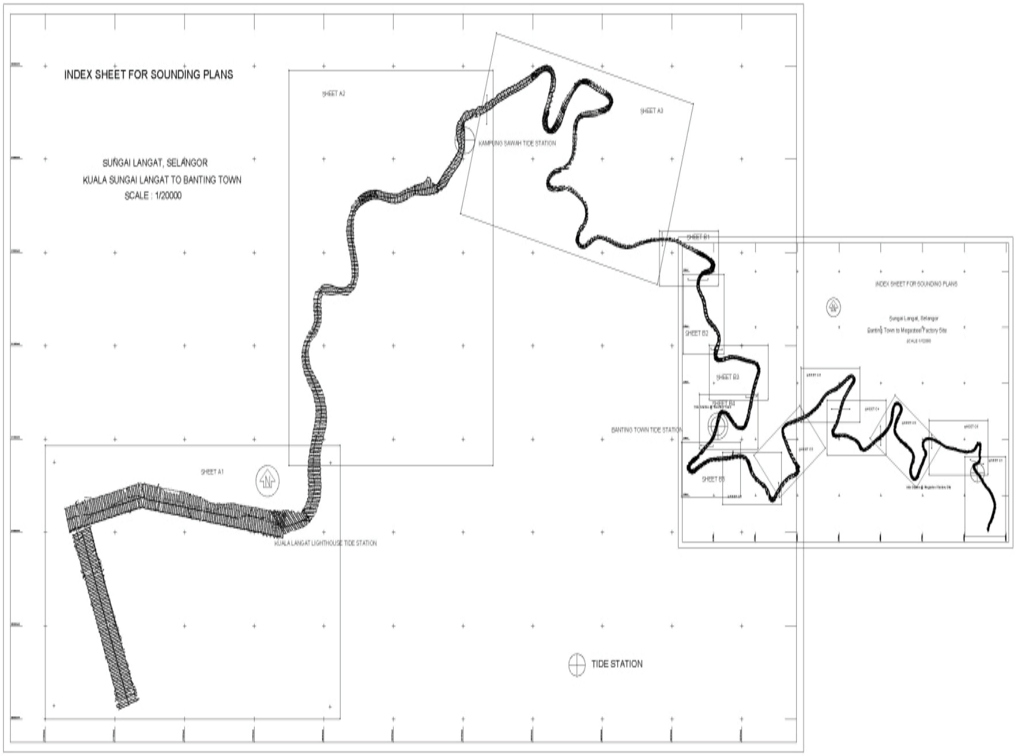


Figure 18: Langat channel complexity.

Empirically derived means to determine the relationship between accident risk, channel complexity parameters and VTS is given by equation

R = -0.37231-35297C+16.3277N+0.2285L-0.0004W+0.01212H+0.0004M (18)

For predicted VTS consequence of 100000 transit, C = 1 for an open approach area and 0 otherwise, N = 1 for a constricted waterway and 0 otherwise, L = length of the traffic route in statute miles, W = average waterway/channel width in yards, H = sum of total degrees of course changes along the traffic route, M = number of vessels in the waterway divided by L.

Barge movement creates very low wave height and thus will have insignificant impact on river bank erosion and generation of squat event. Speed limit can be imposed by authorities for wave height and loading complexity. Human reliability analysis is also important to be incorporated in the channel; complexity risk work, this can be done using questionnaire analysis or the technique of human error rate prediction THERP probabilistic relation.

$$P_{EA} = HEP_{EA}.\sum_{k=1}^{m} FPS_K.W_K.+\mathrm{C} \quad (19)$$

Where: P_{EA} = Probability of error for specific action, HEP_{EA} = Nominal operator error probability for specific error, PSF_K = numerical value of kth performance sapping factor, W_K = weight of (constant), m = number of PSF, C = Constant

Reability based validation: Reliability analysis is designed to cater for uncertainty and to provide confident on the model. It is important for this to be carried out separately. Reliability work could include projection for accident rate for certain number of year the following techniques:

- Accident mean
- Variance and
- Standard deviation from normal distribution

For 10 years =>Mean (μ) = 10 x Na (20)

Variance (σ) = 10 x Na x (1-Na), Standard deviation = $\sqrt{\sigma}$, Z = (X- μ)/ σ (21)

Stochiatic process using poison distribution, year for system to fail from binomial, mean time to failure and poison distribution or determination of exact period for next accident using binomial function. Ship collisions are rare and independent random event in time. The event can be considered as poison events where time to first occurrence is exponentially distributed.

$$Fr\left(\frac{\mathrm{N}}{\gamma,\mathrm{T}}\right) = e^{\gamma.\mathrm{T}}\left(\quad\right)\gamma,\left(\gamma.\mathrm{T}\right)^{N}).\mathrm{N}\,! \qquad (21)$$

Binomial distribution for event that occurs with constant probability P on each trail, the likelihood of observing k event in N trail is binomial distribution.

$$L\left(K / N,P\right) = \binom{N}{P} P^{K}\left(1-P\right)^{N.K} \qquad (22)$$

Where average number of occurrence is NP

Comparing the model behaviour apply to other rivers of relative profile and vessel particular

Triangulating analysis of sum of probability of failure from subsystem level failure analysis

Implementation of TSS is one of the remedies for collision risk observed and predicted in Langat; this can be done through integration of normal distribution along width of the waterways and subsequent implementation frequency model. And the differences in the result can reflect improvement derived from implementation of TSS. Figure 19 shows the impact of waterways variables on implementation of TSS. The revealed that beam of ship play important role in implementation of TSS. Optimum beam is representing by the meeting point of the variables.

$$f_{south\,(X)} = \frac{1}{\mu\sqrt{2\pi}} e^{-\frac{1}{2}}(x-\frac{12}{\mu}) \qquad (23)$$

$$f_{north\,(X)} = \frac{1}{\mu\sqrt{2\pi}} e^{-\frac{1}{2}}(x-\frac{12}{\mu}) \qquad (24)$$

Variables behaviour in implementation of TSS is shown. The meeting Point signified the right beam for the ship to be safe for TSS. The beam plays a very important role in the implementation of TSS.

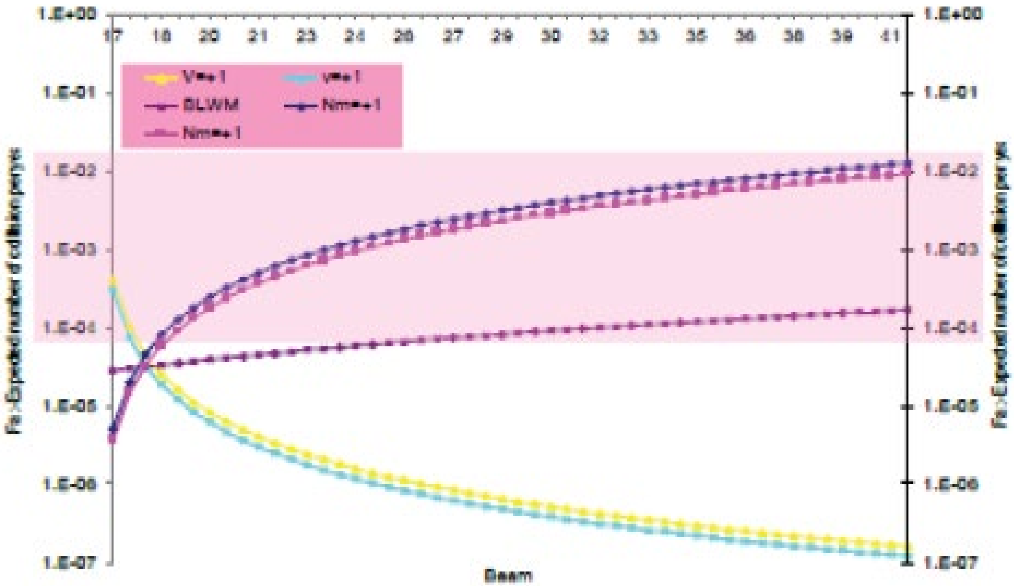


Figure 19: shows the impact of waterways variables on implementation of TSS.

Safety level and cost sustainability analysis. Figure 20 shows the best accident frequency that is acceptable. Ct is is the total cost, Co is the cost of damage and Cc is the cost of repair.

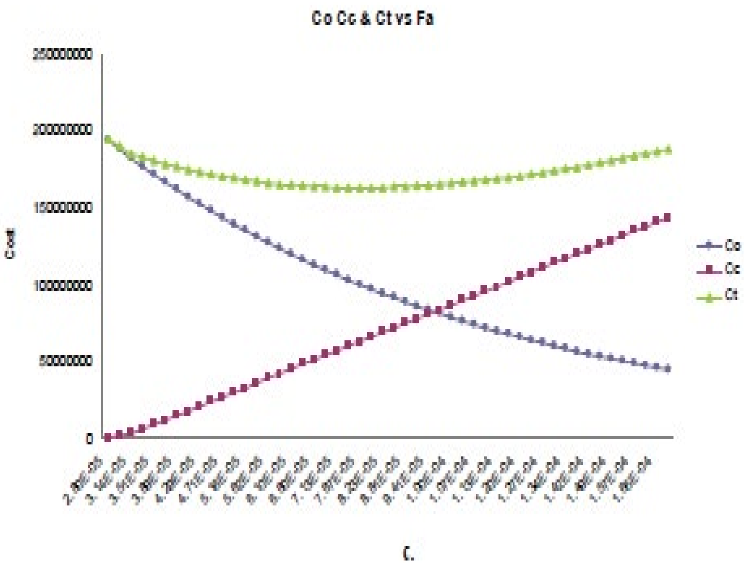


Figure 20: Risk cost benefit analysis.

Reliability based validation: Validation and reliability analysis of the model yield the following result. Figure 21 shows accident frequency residual plot from Minitab is shown with good fitness. Figure 22 Shows accident consequence validations, accident consequence good to fit to the method, residual graph of Cumulative Density Function (CDF) profile tracing infinity. In this analysis Frequency is refer to as Fa or Na.

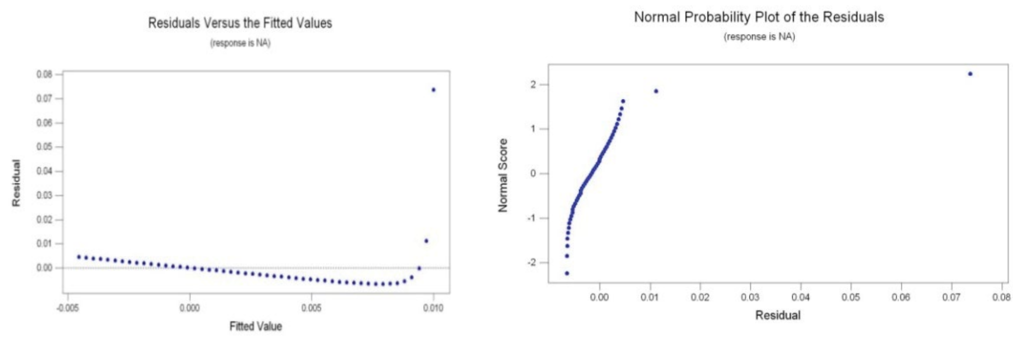


Figure 21: Accident frequency residual plot.

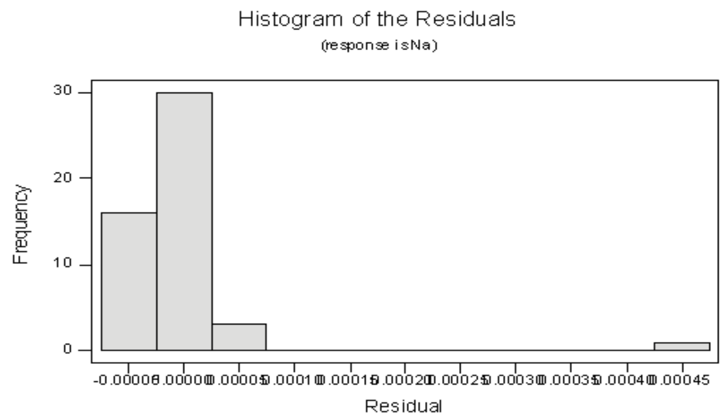


Figure 22: Residual histograms distribution diagram for accident frequency.

Figure 23a Shows Log normal plots Accident frequency (Na), distribution shows a good to fit. Curve Figure 23b also show a very good curve fit for the model.

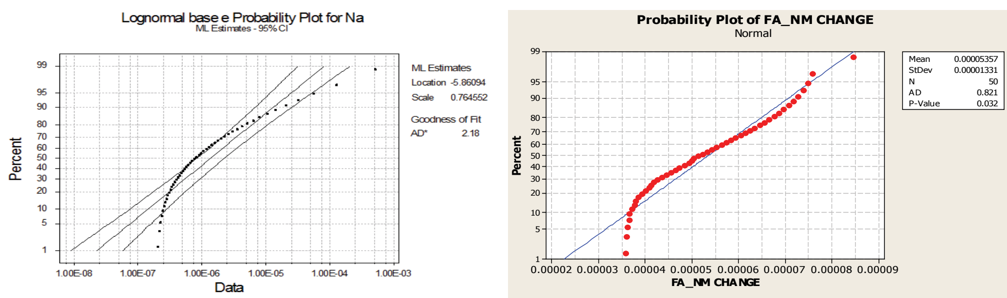


Figure 23: (a) (b): Log normal plot Accident frequency (Na).

Figure 24 shows process reliability capability, the fitting of the curve revealed the reliability of the frequency model

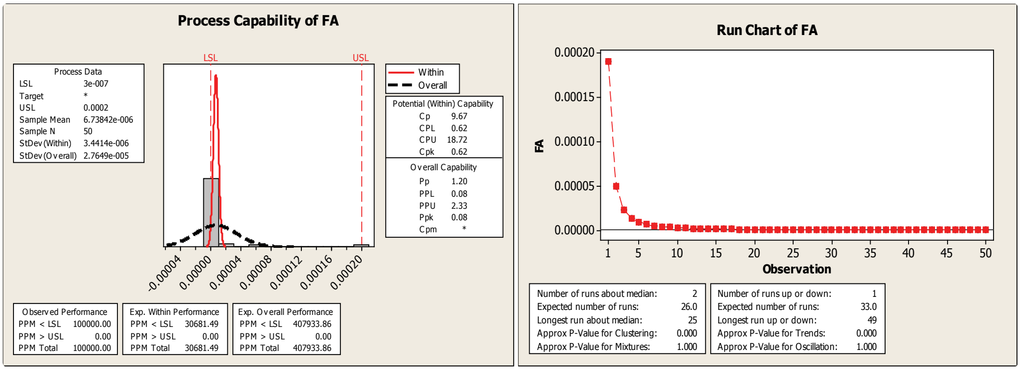
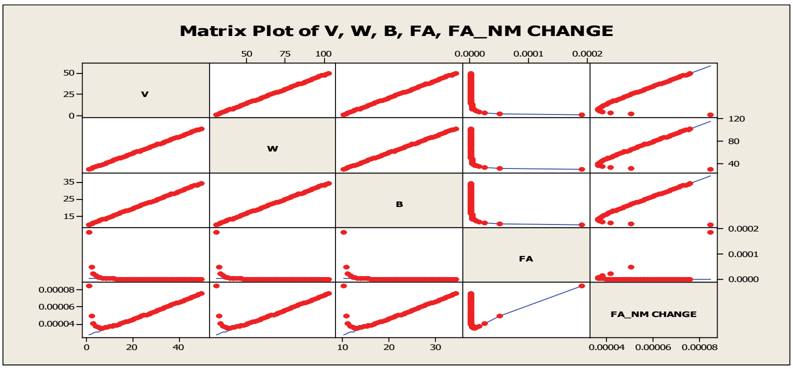


Figure 24: Process capability.

Figure 25 shows the matrix plot for the model, the safe areas for the variable workability are shown in the matrix plot.



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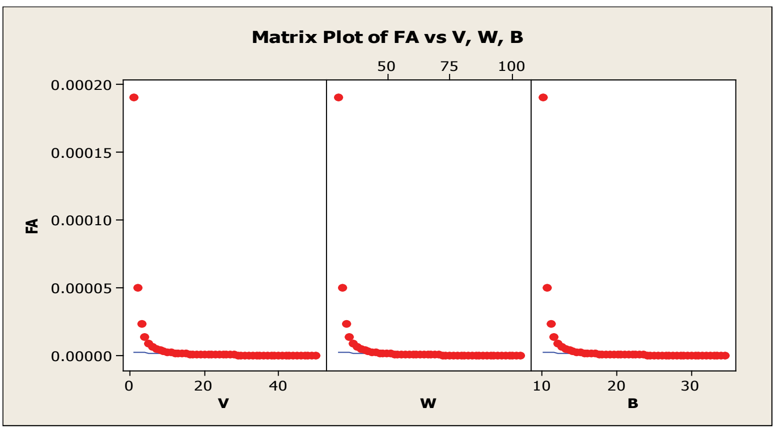
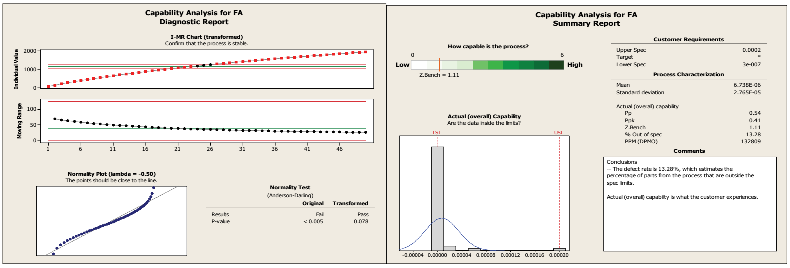
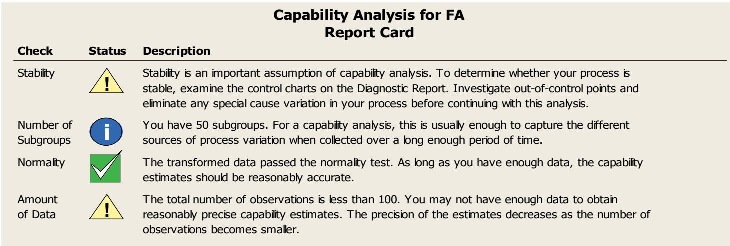


(b)

Figure 25: Matrix plot.



(a) (b)



Capability Analysis for FA
Report Card

Check	Status	Description
Stability	!	Stability is an important assumption of capability analysis. To determine whether your process is stable, examine the control charts on the Diagnostic Report. Investigate out-of-control points and eliminate any special cause variation in your process before continuing with this analysis.
Number of Subgroups	i	You have 50 subgroups. For a capability analysis, this is usually enough to capture the different sources of process variation when collected over a long enough period of time.
Normality	✓	The transformed data passed the normality test. As long as you have enough data, the capability estimates should be reasonably accurate.
Amount of Data	!	The total number of observations is less than 100. You may not have enough data to obtain reasonably precise capability estimates. The precision of the estimates decreases as the number of observations becomes smaller.

(c)

Figure 26: (a) (b) (c): Log normal plot Accident frequency (Na).

Conclusions

Hybrid of deterministic, statistical, historical, probabilistic and stochastic method along with channel and vessel profile baseline data has been used to model accident possibility in waterway in order to meet condition for safe transits, and environmental conditions for inland waterway. Factors such as vessel type and size, traffic density, speed and visibility conditions are major risk factor of accidents the probabilistic method represent reliable method to develop models for safety and environmental prevention and collision accident risk aversion who precedence is could be short term (damage) or long term (impact of oil outflow) environmental impact. Accident collision per number of year has been determined for potential decision support for limit definition for number of ship, speed, required width and beam of ship.Variables that affect accident rates have been simulated for necessary limit acceptability purpose for the channel. Accident rate has increased compare to previous year, a situation that required attention for solution. Advantage of implementing of TSS in respect to beam requirement is also presented. Implications of concept of uncertainty can help also on decision support relating to navigational aids and transit regulations for poor visibility conditions as well has employment of improved navigation systems, such as electronic charts, GPS receivers, and VTS, to mitigate causal factors.

Appendix: Nomenclature

Nm	Number of ship movement	Nm	Number of ship movement
V	Speed	P_i	Probability of impact
T	Draft of the ship	C_{head}	Head on Collision
B	Beam of the ship	C_{ov}	Overtaking Collision
D	Depth of waterways	C_{cr}	Crossing Collision
W	Width of fairy	C_{an}	Collision at specific angle
B_1	Mean beam of meeting ship (m)	C_{Ci}	Collision at circular situation
B_2	Mean beam of subject ship (m)	Pi	Impact probability
V_1	Mean speed of meeting ship (knot)	E_1	Accident drafting collision energy

V_2	Mean speed of subject ship (knot)	E_2	Accident Power collision energy
Theta	Angle	E	Consequence energy
L	Length of ship	P_a	Probability of accident
P_s	Traffic density of meeting ship (Ship/nm2)	P_c	Probability of losing control per passage of the fairway

2. Collision Damage Consequence Risk Reliability for Langat River (Malaysia) Sustainable Inland Water Transportation

Abstract

Accident consequences resulting from collision remain a big threat to coastal water transportation operation. The nature of the threat can be worrisome the danger may involve instantaneous and point form release of harmful substance to water, air and water causing a long time ecological impact. That may lead to the loss of life, damage to the environment, disruption of operation, injuries. This makes scientific risk based design that analyse all components of risk including the quantification for consequences of accident very imperative for reliable design and exercise of technocrat stewardship of safety and safeguard of environmental. System risk has been widely assessed using traditional environmental impact assessment, a checklist based approach that ends up bypassing a lot of uncertainty that comes with complex and dynamic systems. Novel analysis of frequency, consequence, subsystem an4 uncertainty components of system risk using g hybrid of deterministic, probabilistic and stochastic process represent a modest best practice for sustainable system design. This paper discusses the result from analysis of damage components for collision accident towards generic risk mitigation option and decision support required for operational, societal and technological change for sustainable inland water transportation system for Langat River. The risk on Langat River determines by consideration the actual situation of the channel and suppressing the system parameters under pressure and determines the reliability of the trend generated from the model. The present risk consider on Langat is found to be low in the absence with ongoing improvement plan.Accident frequency is of 3.8E-5 and consequence energy of 31 MJ, resulting to length of collapse of 9.3 m. The damage estimation is further simulated for all channel variable parameters to determine the generic risk and reliability condition that can be used for traffic situation limit definition for safety and environmental preventive risk avoidance within inland waterways.

Keywords: Collision; Marine Vehicle; Risk; Reliability; Transportation;

Introduction

Collision risk is a product of the probability of the physical event and the probability of occurrence as well as economic losses. Earlier risk modelling focus more on frequency estimation and leave analysis with more uncertainties to account for, incorporating consequence estimation and quantification make collision risk work more complete. Collision accident scenarios carry heavy consequence thus its occurrence is infrequent. These accidents represent a risk because they expose vessel owners and operators, as well as the public, to the possibility of losses such as vessel and cargo damage, injuries and loss of life, environmental damage, and obstruction of waterways [15]. Like frequency analysis, damage collision data are hard to come by, however available data should be made meaningful as much as possible through hybrid use of available tools especially predictive tools for necessary mitigation decision for sustainable waterways [16]. This paper discusses the modelling of waterways collision risk and associated consequence related with other variables risk factors like vessel characteristics, channel characteristics, traffic characteristics, operator skill, topographic and environmental difficulty of the transit [17]. The paper discuss of implementation of risk and reliability model to prevent collision on Langat River. Determined accident frequencies per year are plotted against the consequence in term of damage and energy release during accident to determine collision risk in one millionth years. The paper also discuss outcome of validation analysis of the model as function of reliability for sustainable IWTS design.

Background

The study area is Langat River, 220 m long navigable inland waterway that has been under utilized. Personal communication and river cruise survey revealed that collision remain the main threat of the waterways despite less traffic in the waterways. This makes the case for analysis of risk and reliability for sustainable development of the waterways a necessity [6]. Data related to historical accidents, transits, and environmental conditions were collected. Accident data are quite few, this is inherits to dynamic and complex system like most Inland Water Transportation System (IWTS). This equally makes probabilistic methods the best preliminary method to analysis the risk, the outcome of which can be optimized through simulation method and expert rating as required Figure 27.

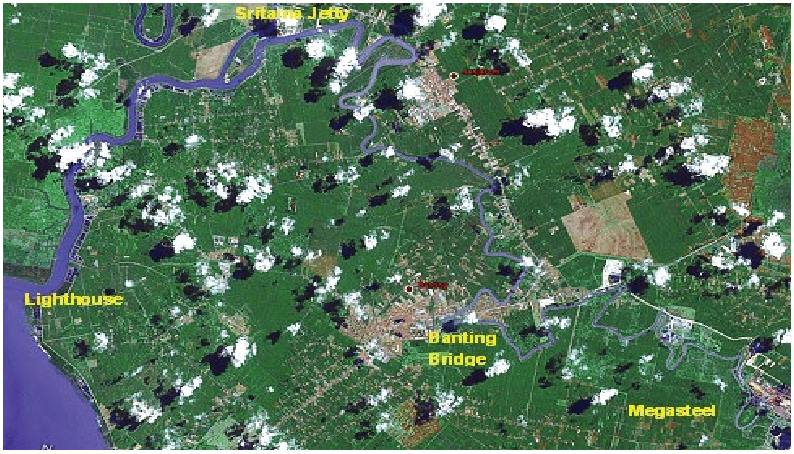


Figure 27: Langat River map.

Barge and tug of capacity 5000T and 2000T are currently plying this waterway at draft of 9 and 15respectively. Safety associated with small craft is not taken into account. Collisions including contact between two vessels and between a vessel and a fixed structure are considered, also, causes of collision are linked to navigation system failure, mechanical failure and vessel motion failure are considered in risk based worked for use of the river for transportation [6]. Below are other information relating to channel, vessel and environment considered employed in the risk process, lacking information about the distribution of transits during the year, or about the joint distribution of ship size and flag particular, environmental conditions are systematically derived of the probabilistic and stochastic estimation process. Figure 27 shows aerial view of Langat River.

Baseline data: The channel width data plays a very important role in possibility of accident and damage caused to physical structures. Therefore beside fatality and societal consequence analysis, extent of damage can be analysed to determine risk of collision in water ways [13]. Figure 28 shows data of channel width parameter required for damage analysis, where the channel width is one of the parameters way traffic, straight channel is 98 m, bend is 120 m and depth is 8 m). Table 17 shows Langat River waterways parameters where Langat River length is represented by 135.7 km, estuarine data Langat in North Estuary is 44.2 km and South Estuary is 9.9 km. The main risk contributing factors can fall under the following: [5]

- Operator
- Vessel characteristics
- Traffic characteristics
- Topographic difficulty of the transit
- Environmental condition including water level and tide
- Quality of operator's information including
- Uncertainty in Surveys/Charts

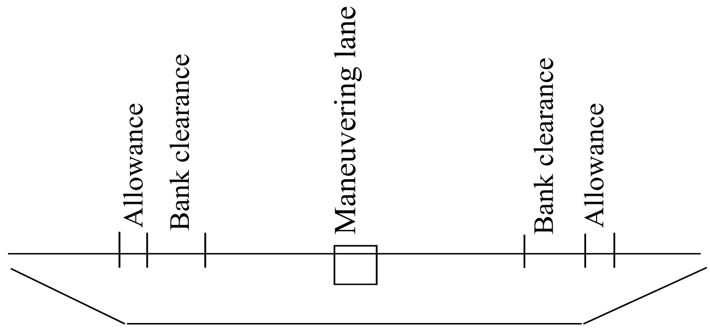


Figure 28: Channel width parameter.

Vessel width parameter plays a very important role in collision scenario and potential damage. Vessel movement for the case under consideration currently has no vessel traffic separation system. However, there is traffic movement from both inbound and out bound navigation in the channel. The same type of barge size is considered for the estimation work [14-17]. Table 17-19 shows barge and tug parameter use for the analysis of vessel on Langat River. Figure 29 shows Langat River vessel and channel requirement.

Basic Maneuvering Lane	1.5B
Addition for cross wind (less 15 knots)	0.0B
Addition for cross current (negligible<0.2 knots)	0.0B
Addition for bank suction clearance	1.0B
Addition for aids to navigation (Excellent)	0.0B
Addition for cargo hazard (medium)	0.0B
Channel width for Inland Waterways (B= Beam of the ship)	2B=53m
Channel width at Bend	3.0B = 64m

Table 17: Waterway parameter.

Barge parameter	2000 tons	5000 tons
Length (m)	67.3	76.2
Beam (m)	18.3	21.3
Depth (m)	3.7	4.9
Draft (m)	2.9	4.0

Table 18: Vessel requirement, Barge and Tug parameter.

Tugs parameter	2000 tons	5000 tons
Length (m)	23.8	23.8
Beam (m)	7.8	7.8
Depth (m)	3.5	3.5
Draft (m)	2.8	2.8
Horse Power (hp)	1200	1200

Table 19: Vessel requirement, Barge and Tug parameter.

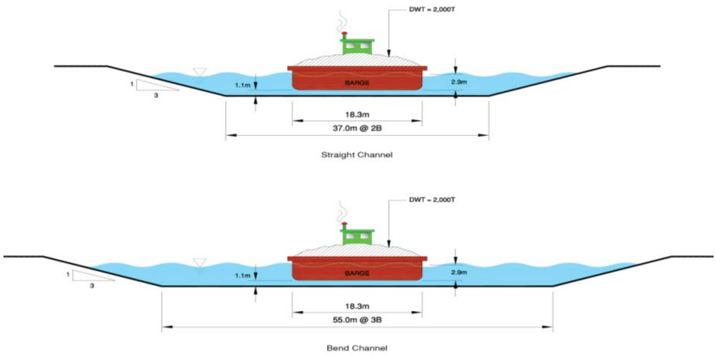


Figure 29: Langat vessel requirement.

Risk analsys modeling: The reliability process involves deriving rate of accident from deterministic first principle, historical data, probability and stochastic estimation. Individual risk involve hypothetical individual who is positioned there for 24 hours per day, 365 days per year. Average individual risk is usually qualitatively calculated from historical data [18].

Individual risk = Number of fatalities/number of people at risk (1)

Individual risk per year and Fatal Accident Rate (FAR) for workers are commonly expressed as a Fatal Accident Rate (FAR), which is the number of fatalities per 108 exposed hours. FARs are typically in the range 1-30 and are more convenient and readily understandable than individual risks per year, which are typically in the range 10-5-10-3. FAR can be expressed as:

Onshore FAR = Fatalities at work x 108/Person hours at work (2)

Conversion between Individual Risk and FAR when calculated in a risk analysis, the FAR is usually derived from the calculated individual risk of death per year, divided by the number of hours exposed in a year x. the conversion from individual specific risk to FAR is:

FAR = Individual - specific risk per year x 108/3360 hours per year (3)

Conversion between individual risk and group risk related using the Personnel on Board (POB) as follows; this conversion is only recommended as a check. It is preferable to calculate individual and group risks separately. Expectation Value (EV) of group risk is the correct mathematical term, but makes the risk sounds inevitable. Potential Loss of Life (PLL) per year is also sometimes used for the expectation value of lifetime group risk as the life time fatality rate or Rate of Death (ROD).

In the fatality estimation, the consequences of each scenario can be represented by the probability of death for an individual initially at a particular location on the platform when the event occurs. In hydrocarbon events, the overall probability of death is calculated from: Probability of local fatality in the fire/explosion $P_{fl,}$ Probability of fatality during escalation/ mustering $P_{fm,}$ Probability of fatality during evacuation P_{fe} . The total fatality probability P_F is:

$$P_F = P_{fl} + P_{fm}(1 - P_{fl}) + P_{fe}(1 - P_{fm})(1 - P_{fl}) \quad (4)$$

The Location Specific Individual Risk (LSIR) for a hypothetical individual continuously present in a particular area of the accident location is:

$$LSIR = \sum_{\text{allscenarios}} F_s P_F \quad (5)$$

Where F_s frequency of scenario, P_F is probability of death in the scenario for an individual at the location, the Individual Specific Individual Risk (ISIR) for the specific groups of workers from events on the platform is:

$$ISIR = \sum_{alllocations} LSIR * P_L \qquad (6)$$

P_L is the proportion of time an individual spends in a location

The Fatal Accident Rate (FAR) for each group of workers is:

$$FAR = \frac{ISIR * 10^8}{H} \qquad (7)$$

Where H is the hours offshore per year (3360 hours per year is a typical value)

For group risks, the total number of fatalities in the scenario is given by:

$$N_F = \sum_{Locations} P_F N_L \qquad (8)$$

N_L represents average number of people on location

Group (or societal) risk involves the risk experienced by the whole group of people exposed to the hazard. It is interchangeable with group risk. Societal risks may be expressed in the form of Frequency Number (FN) or Annual fatality rate (AFR). FN curves show the relationship between the cumulative frequency (F) and number of fatalities (N), annual fatality rates, in which the frequency and fatality data is combined into a convenient single measure of group risk. For each scenario, frequency fatality (FN) curve can be obtained. The annual fatality rate is given by:

$$AFR = \sum_{allscenarios} F_S N_F \qquad (9)$$

Alternative damage costs estimate could be modelled using the consequence analysis, where damage fraction is estimated for each scenario. This is equal to the cost of the accident as a fraction of the total infrastructure cost. For fires and explosions, the consequences of each scenario may be represented by fractions of each module's volume damaged. The total terminal damage fraction is:

$$D_F = \sum D_m * C_m / C_t \qquad (10)$$

Where: D_M fraction of module damaged, C_m/C_t cost of module as fraction of terminal cost. The annual damage fraction is represented as:

$$ADF = \sum_{scenarios} F_S * D_F \qquad (11)$$

Oil Spills is another consequence analysis where the quantity of oil spilled, S is estimated for each scenario.

The annual spill rate is given by:

$$ASR = \sum_{allscenarios} F_S * S \qquad (12)$$

Damage data requirement: Collision data are drawn from relevant marine administrator, previous risk work for complex system like offshore. There is expectation that most gaps will be covered by stochastic and probability estimations. The Langat River work model involve systemic risk and reliability analysis using scientific procedures for inland waterways risk to deduce the probability of failure or occurrence, consequence risk ranking, damage estimation, high risk to life safety, cost benefit analysis and sustainability and acceptability criteria [19] Table 20 and 21.

Case	Hit
Hit	2 nos. of concrete pile have a scratched mark. 5 nos. of concrete pile were broken.
	The protection pipe at the nearby jetty was damaged & missing. 3 nos. of welded pipe were missing.
Hit/ Tug and vessel	The protection pipe at the nearby jetty was damaged & missing. 3 nos. of welded pipe were missing/ bended I- beam
	Temporary jetty at Pier 9a.
	I-Beam that is used for Gen-Set was bent. Workers jetty was badly damage.
	Bended I-Beam.
	Protection pipe at Pier 9a.
	Temporary jetty at Pier 9a. Welding set & crane collapsed & sank into the river.

Table 20: Chronology of accident along Langat River due to inland navigation activities.

Operation parameters	Activities
Jetty	3 nos
Daily	9 times
Weekly	63 times
Montly	252 times
Annually	3024 times
Total	12 nos. of barge will used every day (24hours)
Incoming	6 nos every 4 hours
Outgoing	6 nos every 4 hours
Speed	2-3 knots
Traffic situation	Single way traffic
Layby	Four

Table 21: Tug boat & vessel activities along river for 2008.

Couple with the analysis of annual frequency of occurrence, potential accident causal factor and damage consequence in term of energy of hit resulting from collision of vessel is studies. Ship barge and tugs of 5000T and 2000T having respective draft of 9-15 m is presented in Table 21 where, magnitude of hit are described theoretically. By using probabilistic risk method, system uncertainty can be uncovered under absolutism principle of discrete probability. Seasonal trends and limit is estimated from result of stochastic process outcome and system behavior. Limitations of data for high risk complex and dynamic system like inland water ways demand use of hybrid use of historical and stochastic analysis. Future data collected during monitoring and simulation can open opportunity to cover deficiencies gap, validation work, improved analysis and understanding of accident risk. The general hypothesis behind assessing physical risk consequence model is to determine the probability of an accident impact and energy release on particular events and the variables that make magnitude of the consequences more meaningful for decision support input [20].

Damage estimation analysis: Based on available accident statistics and the results from the Hazard analysis, eight generic accident scenario umbrellas that required deep analysis are: collision, fire or explosion, grounding, contacts, and heavy weather/loss of intact stability, failure/leakage of the cargo containment system, incidents while loading or unloading cargo, emission of ship power sources [21]. It is recommended that further efforts should focus on measures relating to safety function impairment like [22]:

Risks of safety function impairment:

- Damage Risks
- Annual damage cost
- Frequency Cost (FC) curves
- Oil Spills, annual spill rate

- Frequency Damage size (FD) or Frequency energy curves
- Risk Measures for Loss of Life

Initial kinetic energy of ship $(E)=\frac{1}{2}\frac{M}{1000}V^2.\mathrm{K}(MJ)$ (13)

Where: E = impact energy (MJ), M= vessel mass (tonnes), V= vessel speed

K= hydrodynamic added mass constant, taken as

K factor assignment of 1.1 for head on collision (powered) impacts, and 1.4 for for broadside (drifting)

Absorbed collision impact Ea= 47.2.Vc+32.8 (MJ) [16] (14)

Where, Vc = collapse material volume (m^3)

Interpolation between equation 1 and 2 could give an estimate of how much volume damage is experienced in collision case. Advantage derived from channel improvement work like channel widening, deepening and straightening could be quantified into sustainability equity for determination of cost control option required to reduce further and future risk in the channel [23].

$$Na = \frac{1}{2}.\mu_c.D.Pi.Nm \quad (15)$$

Total integrated risk is represented by:

Rt= fs (Rc, Re, Rs**)** +Rw +Rh (16)

Where, Rc (crew) = fc (qualification, fatigue). re (environment), fe (sensitivity, advert weather), Rs (ship) = fs (structural and system reliability, ship layout and cargo arrangement). Rw = Fw (water way, channe.l), Rh = Fh (Human reliability analysis). Table 22 shows consequence of risk acceptability criteria for maritime industry.

Limited	Consequence limited to accident area with no public impact	Impact Energy <40 MJ
Minor	Impact has no consequence on public health	50 MJ
Serious	potential for serious injury	Impact Energy >50 MJ
Extensive	potential for fatality	

Table 22: Consequence acceptability criteria.

The consequence could further be broken down into effect for ship, human safety, oil spill and ecology.

Result presentation

Figure 30a shows that head on collision has the highest risk potential as the curve touch ALARP high risk area. Derived equation for each collision is shown in the graph. Figure 30b shows expected number of impact (Ni), accident energy at variable speed plot for head on collision, as the number of ships in the waterway increases. Figure 30b shows that there is higher risk and potential rise in Ni as the number of ship in the channel increase, 1 to 2 number of accident is likely to occur. Interestingly, the graph also shows that the risk of accident of occurrence is possible when the speed is moving at much lower speed. For 3 number of ship in the channel navigating at 4 knot, there is likelihood of 0-1 accident occurrence. Figure 30c shows that, for overtaking collision, at 3 number of ship that Langat is currently operating there is likeliness of zero a-1 accident for overtaking collision, accident will only occur if vessel slows down less than 1 knot.

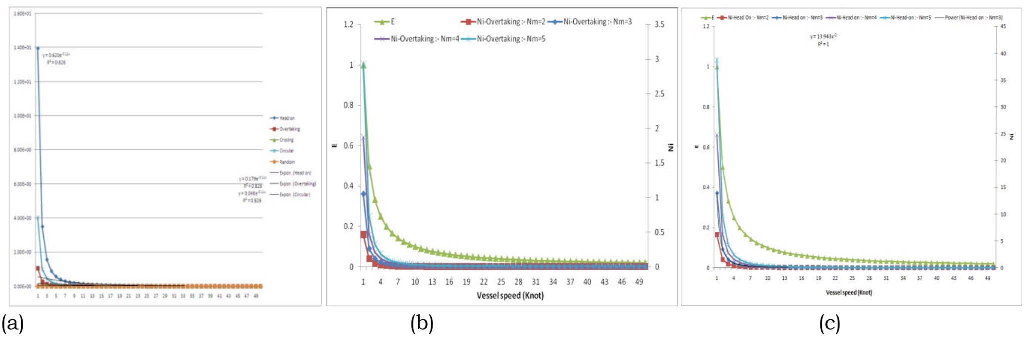


Figure 30: a. Collision risk potential for different collision situation, b. Number of accident impact vs speed and number of ship traffic and accident energy for head on collision situation c. Number of accident impact vs speed and number of ship traffic and accident energy for overtaking collision situation.

Figure 31a shows relationship between Ni and velocity, from the graph there is high probability for accident occurrence between 90 and 150 following precision principle, where high impact can be experienced if accident happens at that angle and at speed of about 12 knot. Figure 31b shows relationship between Ni, released energy and volume of collapse for different accident situation. Excess number of Ni up to 7-8 with high energy release and catastrophic volume of collapse up to 14 cubic meters can occur at the point where the energy and Ni graph meet.

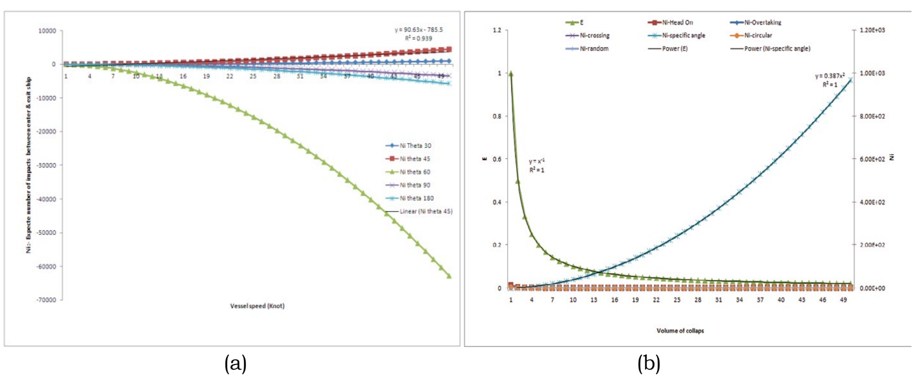
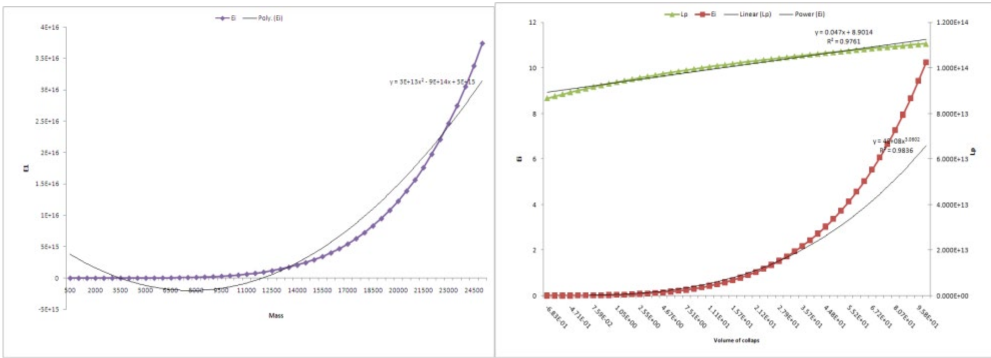


Figure 31: a.Number of accident impact vs angle of collision b.Number of accident impact, accident released energy and volume of collapse for different collision situation.

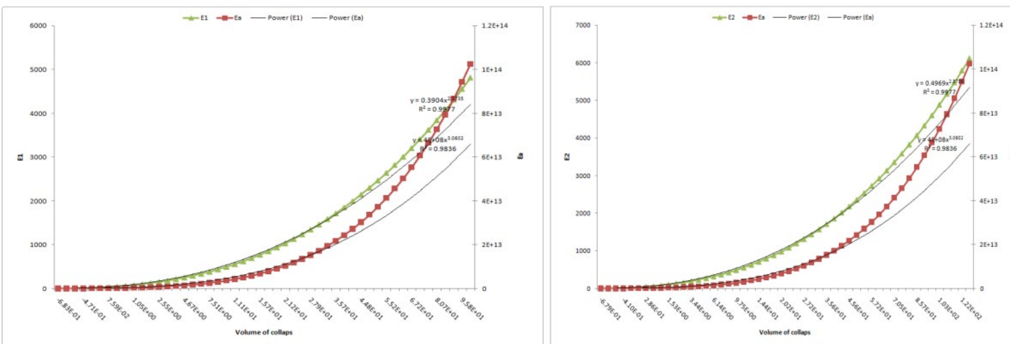
Figure 32a shows the mass and energy release relation for vessel mass of 5000 t, there is 12 MJ of energy released, while for vessel mass of 2000t, there is 1.2 MJ of energy released. The derived equation for the trend can be used for model iteration and validation of model of similar waterway profile. Figure 32b shows relationship between impact energy, volume of collapse (Vc) and length of penetration (Lp). The gragh shows that at avaerage enegry (Ea) of 36 MJ, power colision energy (Ep) of 39 MJ, the lenght of collapse is about 11 m.



(a) (b)

Figure 32: a. Accident consequence energy and mass, b. Impact energy, volume of collapse and length of collapse.

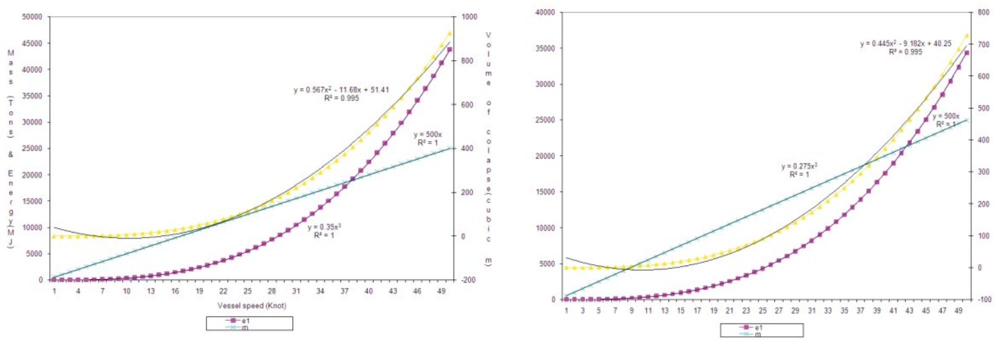
Figure 33a shows the energy and volume of collapse relation for powered collision energy (Ep), drifting collision (Ed) and interpolated average collision energy (Ea). It is observed that volume of collapse of 51 cubic meter occur at 12 MJ release of energy from Ep and 27 MJ from Ea, the speed at this point is observed to be 8-12 knot, catastrophic energy will occur at speed of 38 knot, at point where E1, Ea and VC are equal with respective value of E1= 3000MJ, Ea is 3008MJ and Vc is 60 cubic meter. Similarly result is observed for drifting collision as shown in Figure 33b. The value is a bit higher for drifting colision and the gragh of drifting colision is much more steeper than the gragh of powered collision. Driftng collision, for example can be due to lost of mooring function, that can consequentially leads to vessel moving at higher spped to nearby structure while powered colision can be due to loss of propulsion function. Respectively subsytem level risk analysis can be perform for cause of cause function using fault three and event tre analysis to deduce much more reliability on the system.



(a) (b)

Figure 33: a. Powered collision energy and volume of collapse, b. Drifting collision energy and volume of collapse.

Figure 34a and b show variation in accident consequence, mass of ship and volume of collapse, at curent speed of 3 knot the maximum mass of vessel that can give minimum volume of collapse of 0494 is 1500t and 9.45 MJ energy. The accepable energy for low impact event is below 50 MJ, which can lead to 3.1 volume of collapse at allowable speed of at speed of 5knot. For vessel of of 2000 t mass, there is release of 224 MJ of energy and 0.22 cubic meter of volume of collapse, for vessel of 5000 t mass, there is release of 35 MJ of energy and 6.7 cubic meter of volume of colapse. The derived equation for volume of colapse is $y = 0.567x^2 - 11.68x + 51.41$ with corelation of 0.995 correlation. The equation derived for energy trend is trend is $y = 0.35x^3$ with correlation of 1, while the derived equation for mass is 500 x at $R^2=1$. Catastrophic volume of colapse can occur at 90 cubic meter with of vessel mass up to 12300t. Also it is observed that vessel of up to 19000t could lead catastrophic relase of energy up to 19205 MJ.



(a) (b)

Figure 34: a. Powered collision mass, energy, volume of collapse and speed, b. drifting collision.

ALARP principle, risk acceptability criteria, and risk control option:

The acceptability matrix is based on ALARP principle. The ALARP outcome risk influence curve can be compared with risk acceptability criteria in offshore in maritime industry. This is followed by risk control option and sustainability balancing of cost and benefit towards recommendation for efficient, reliable and effective decision. This is followed by risk acceptability criteria whose analysis is followed with cost control option using cost of Averting Fatality Index (ICAF) and ALARP Principle. Risk acceptability criteria established in many industries and regulations to limit the risk. Risk is never acceptable, but the activity implying the risk may be acceptable due to benefits to safety, environment and economy, reduction of fatality, injury, individual and societal risk. Perception regarding acceptability is described by the rationality may be debated, societal risk criteria are used by increasing number of regulators. The outcome of risk and reliability work on Langat River revealed that the current situation acceptable but indication about increase number of accident per year for a channel of such magnitude posed lots of question to be answered before the elapse of millionth years.

Figure 35a shows the accident frequency per annum and consequence energy graph at changing speed, the current situation on Langat River good The situation only become risky at 0.00035 and corresponding volume of collapse of 2.07E+07. Similar comparative studies revealed the same trend on the length of penetration, where deep penetration into struck structure can start to occur at 7.18 m. Figure 35b shows a cross plotting for accident frequency and consequence at changing speed, the trend revealed that maximum speed for Langat is 4 knot if all safety requirements are in place. The risk at that point is 2.1786E-05 x 20 MJ.

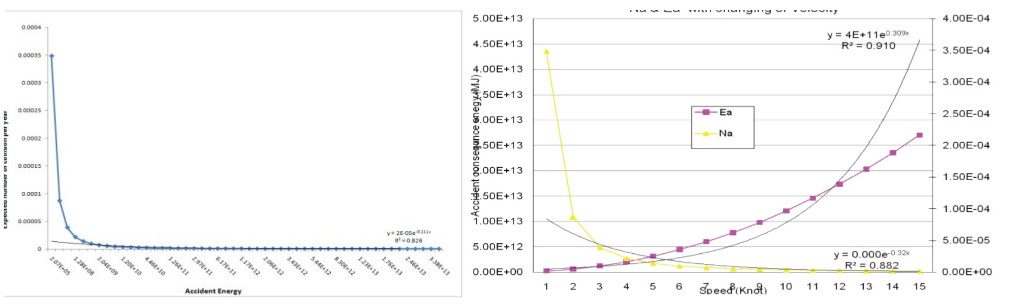


Figure 35: a. Accident frequency and accident energy, b. Cross plot for accident frequency and consequence at changing speed.

Figure 36a shows the graph frequency and damage (volume of collapse) graph, from the graph figure, based on ALARP principle and sustainability analysis, decision can be made for waterways requirements. The ALARP influence diagram show at that a speed of up 7 knot there will be likehood of high accident for the waterways and energy of impact of about 137.5 MJ which is considered a high consequence energy. It is also observed from the figure that positive volume of collapse of 1.3 cubic meters occurs at 7.1E-5. Thus, the risk curve at maximum acceptable is value of 0.0035 is at the top ALARP high risk area; from that point interestingly accident is likely to occur at reduced speed. Similar trend is observed for accident frequency and volume of collapse for drifting collision except that, with a small difference of 0.01 cubic meters (See Figure 36b). Figure 36c shows that acceptable risk at 10e + 4 is at length of penetration equivalent to 7.1 m.

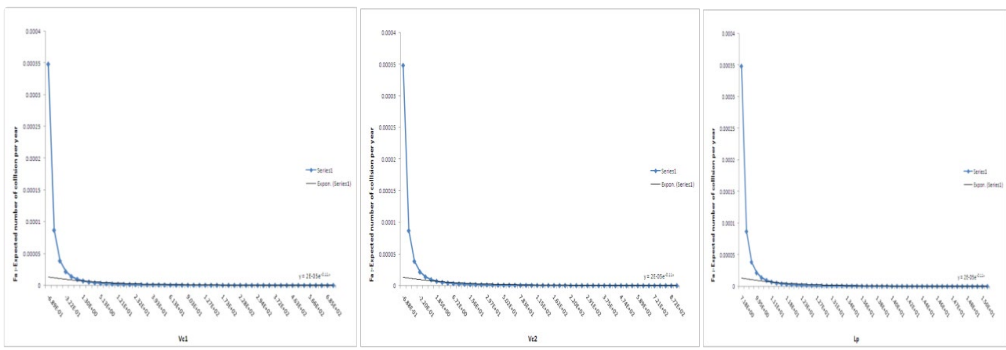
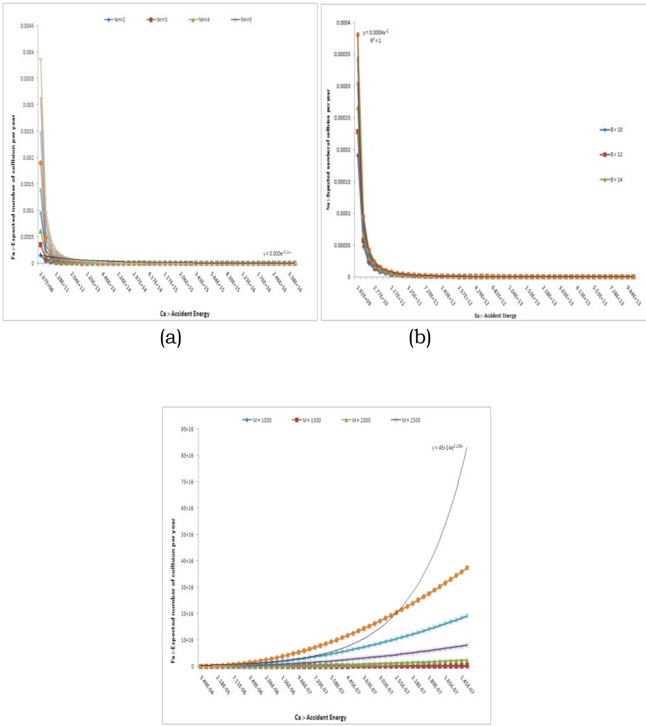


Figure 36: ALARP graph of Accident frequency Vs Consequence volume of collapse for powered collision, b. ALARP graph of Accident frequency length of penetration, c. ALARP graph of Accident frequency Vs Consequence length of penetration.

Figure 37a shows respectively risk situation for accident frequency at changing number of ships, risk become higher with more number of ships. Figure 37b shows accident energy vs accident frequency@changing beam of ship, risk become higher at large beam of ship. Figure 37c shows accident energy vs accident frequency@Changing mass, vessel mass of 10000 t, pose highest risk for collision.

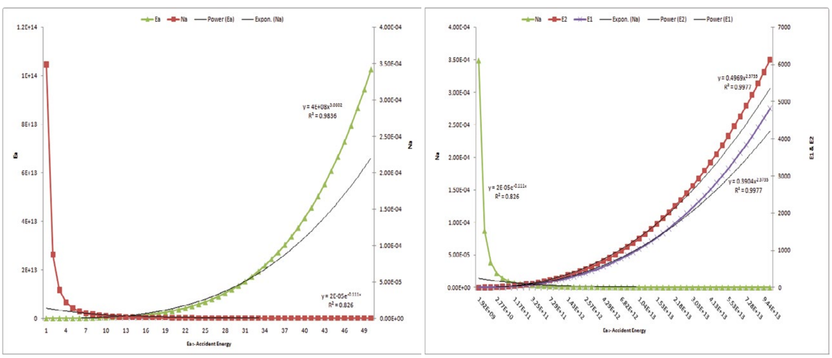


(a) (b)

(c)

Figure 37: a. Accident frequency and consequence energy at changing number of ships, b. Accident frequency and consequence energy at changing beam of ship, c. Accident frequency and consequence energy at mass of ship.

Figure 38a shows accident average energy and accident occurrence frequency. The maximum speed that should not be exceeded is when Fa is 2.06E-06, and Ea is72E-MJ. For the current speed of 3 knot at Langat River, Ea value is 14 MJ and Ea is 3.8e-5. Figure 38b shows the limit definition for risk when the graph of drifting and powered collision are combined. The point 64 MJ, E2 is 82 MJ and 2.8 E-6 represent point of limit definition against catastrophic release of energy.



(a) (b)

Figure 38: a. Cross plotting for accident frequency and accident consequence energy Vs consequence energy@changing beam of ship.

Between reliability and validation: Reliability analysis is required to have assurance about the model; the purpose of reliability testing is to discover potential problems with the design as early as possible and, ultimately, provide confidence that the system meets its reliability requirements. Reliability testing may be performed at system and subsystem level. It can be conducted in the following way for a system in question [24]:

Accident mean, variance and standard deviation from normal distribution

For 10 years =>Mean (μ) = N x Fa (17)

Variance (σ) = N x Fa x (1-Fa) (18)

Standard deviation= $\sqrt{\sigma}$, Z = (X- μ)/ (σ) (19)

Year for system to fail from binomial, mean time to failure and poison distribution.

$$Fr\left(\frac{\mathrm{N}}{\gamma,\mathrm{T}}\right) = e^{\gamma.\mathrm{T}}(\ )\gamma,(\gamma.\mathrm{T})^{N}).\mathrm{N}! \tag{20}$$

Implementation of TSS is one of the remedies for collision risk observed and predicted in Langat; this can be done through integration of normal distribution along thewidth of the waterways and subsequent implementation frequency model. The differences in the result can reflect improvement derived from implementation of TSS.

$$f_{south\,(X)} = \frac{1}{\mu\sqrt{2\pi}} e^{-\frac{1}{2}}(x - \frac{12}{\mu}) \tag{21}$$

$$f_{north\,(X)} = \frac{1}{\mu\sqrt{2\pi}} e^{-\frac{1}{2}}(x - \frac{12}{\mu}) \tag{22}$$

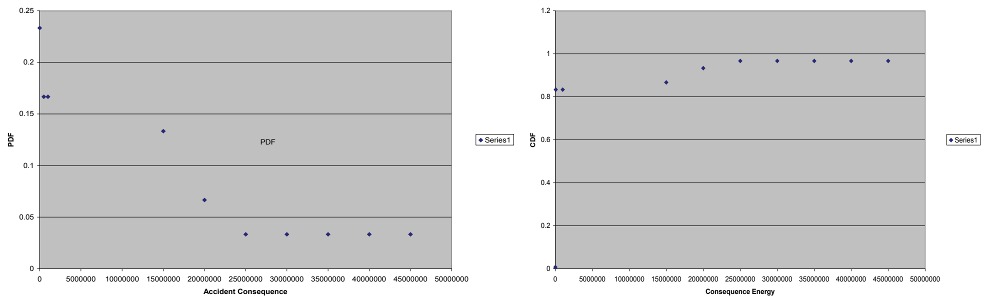
Comparing the model behavior applied to other rivers of relative profile and vessel particular, Triangulating analysis of the sum of probability of failure from subsystem level failure analysis, Probability Density function (PDF) and Cumulative Density Function (CDF) of the model determination. Calculate the cumulative probability of each residual using the formula. PDF can be systematically represented by the histogram curve while CDF is calculated from:

P(i-th residual) = $i/(N+1)$ (23)

Table 23 shows sample consider for accident for accident damage for PDF and CDF estimation. Figure 39a and b show theoretical PDF and CDF plots for sampled data. The CDF tailing assymptote, while the PDF has exponential droping is sign of good reliability for the data used to generate the trend. Damage distribution based on 10 ship accidents per year.

Damage size	Frequency of damage	Damage size	Frequency of damage
100-500	7	5000-10000	4
500 – 1000	6	10000-15000	2
1000-5000	5	15000-100000	1

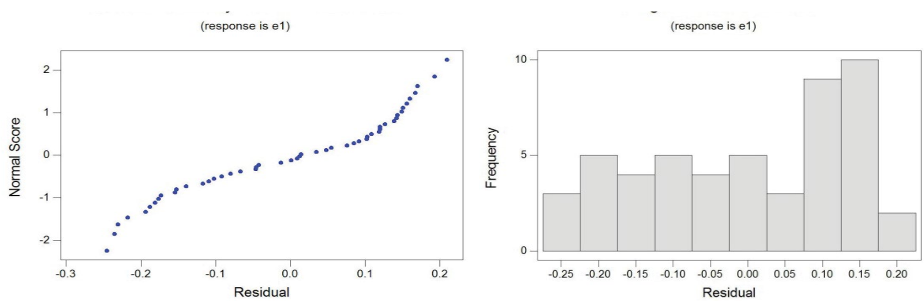
Table 23: Damage size.



(a) (b)

Figure 39: Theoretical PDF and CDF plot. a. Probability density function for accident consequence, b. Cumulative density function for accident consequence.

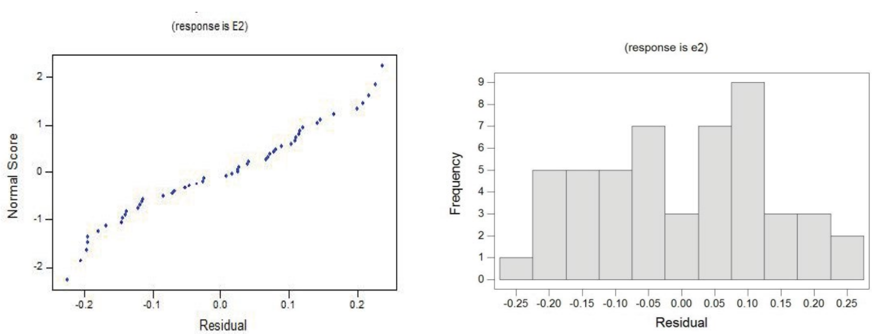
Figure 40a and b show collision impact variation for powered collision energy E1, normal distribution and histogram curve fit is good. On average the damage distribution is acceptable. The overall pattern of the residual observed is similar for the plot of histogram of normally distributed data. Thus the S-shaped curve on the normal distribution graph give indication of bimodal distribution of residuals.



(a) (b)

Figure 40: Collision damage impact (Powered collision) a. Normal distribution plot for E1 residual, b. Histogram plot of the e1 residual.

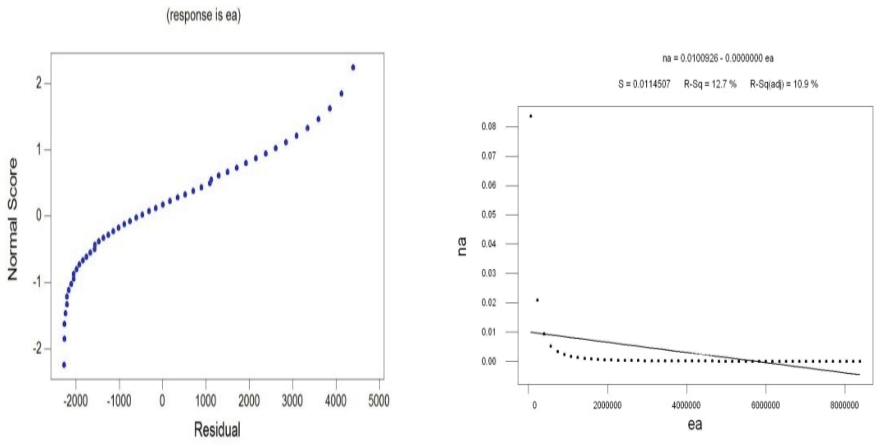
Figure 41 a and b show collision impact variation for drift collision (anchored ship).



(a) (b)

Figure 41: Collision damage impact (Drifting collision) a.Nomal Probability plot of the residual, b. Histogram plot of the residual.

Figure 42 shows collision impact for alternative interpolation for collision energy (Ea) with respective volume of collapse, curve fit is good, The regression work show standard deviation of 0.00115 and correlation up to 86.



a. b.

Figure 42: Collision impact and volume of collapse for alternative interpolation a. Normal probability plots if the residual b. Regression for the risk curve.

Figure 43 shows curve fit and residual analysis for frequency and consequence risk model on Langat River. Figure 44 shows matrix plot for accident frequency and consequence, the graphs shows scatter plot of response with good pattern of inter relationships among the predictor variables. It shows that there is no much gaps and outlying in the data points. From the, matrix curve it is observe that risk is totally unacceptable for reckless increase in number of ship and also high speed. The matrix observation also show that B and w parameter risk are tolerable for long-term.

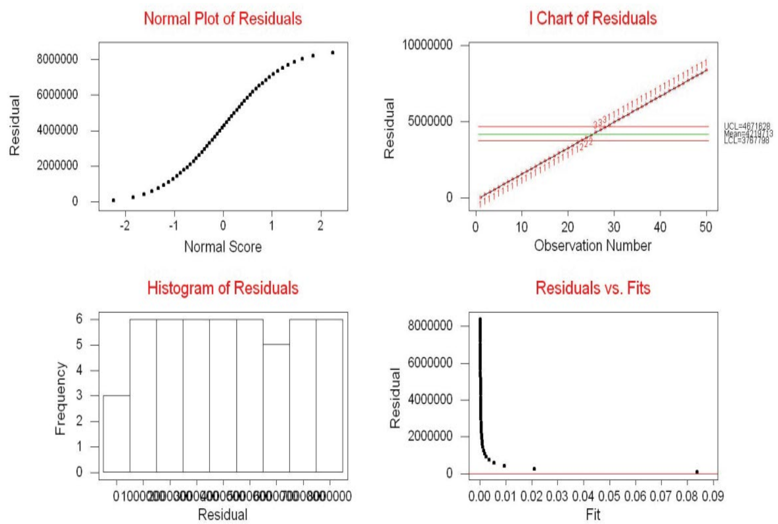


Figure 43: curve fit and residual analysis for frequency and consequence risk model on river Langat.

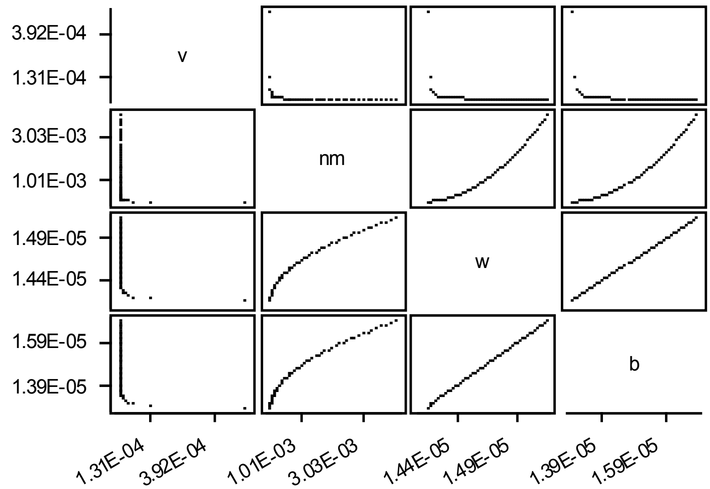


Figure 44: Matrix plot for accident frequency and consequence.

Channel complexity analysis: Various channel components enter channel complexity components, these can be visibility weather, squat, bridge, river bent, human reliability. It is important to Account for each of them in channel design work. Figure 45 show channel complexity for Langat. Poor visibility might be expected to increase the risk of groundings and collisions [25]. The increase in accident risk due to poor visibility is more consistent and more significant than the change associated with high wind. A model extracted from Dover waterway studies concluded with the following:

Fog Collision Risk Index (FCRI) = $\left(P_1 + VI_1 + P_2 + VI_2 + P_3.VI_3\right)$ (22)

Where: P_K = Probability of collision per million encounters, VI_K = Fraction of time that the visibility is in the range k, K = Visibility range: clear (>4km), Mist/Fog (200m-4km), tick/dense (less than 200m).

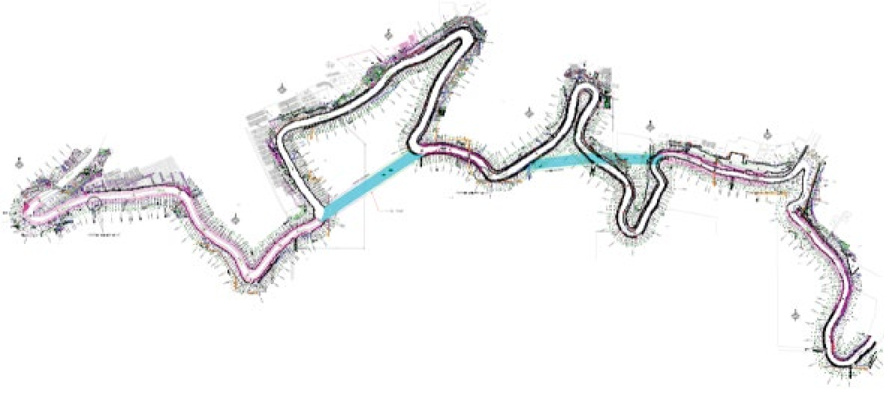


Figure 45: Langat channel complexity.

Empirically derived means to determine the relationship between accident risk, channel complexity parameters and VTS is:

$$R = -0.37231 - 3.5297C + 16.3277N + 0.2285L - 0.0004W + 0.01212H + 0.0004M \quad (23)$$

Where, predicted VTS-consequence 100000 transit, C = 1 for an open approach area and 0 otherwise, N = 1 for a constricted waterway and 0 otherwise, L = length of the traffic route in statute miles, W = average waterway/channel width in yards, H = sum of total degrees of course changes along the traffic route, M = number of vessels in the waterway divided by L.

Barge movement creates very low wave height and thus will have insignificant impact on river bank erosion. Speed limit can be imposed by authorities for wave height and loading complexity [26]. Other important analysis is reliability analysis for uncertainty estimation. It is important for this to be carried out separately. Reliability work could include projection for accident rate for certain number of year, using poison distribution or determination of exact period of next accident using binomial function. Ship collisions are rare and independent random event in time [27]. The event can be considered as poison events where time to first occurrence is exponentially distributed

Another critical reliability stochastic estimation is human reliability assessment which can be done using questionnaire analysis or the technique of human error rate prediction THERP probabilistic relation.

$$P_{EA} = HEP_{EA}.\sum_{k=1}^{m} FPS_K.W_K. + \mathrm{C} \quad (24)$$

Where, P_{EA} = Probability of error for specific action HEP_{EA} = Nominal operator error probability for specific error, PSF_K = numerical value of kth performance sapping factor, W_K = weight of PSF_K PSF_K (constant), m=number of PSF, C= Constant.

Navigation of vessel in shallow water at a hull displacement cause vertical sink age, or squat, as a result of a pressure drop beneath its hull to avoid ship groundings with possible severe economic and environmental consequences, the relevant governmental, port and maritime agencies and organizations need a reliable method of predicting ship squat [9]. Squat analysis of squat and channel clearance based on the physical characteristics of a channel and the ships that travel through it can be used to issue appropriate regulations regarding vessel size and speed and to plan channel dredging operations. Model on weather and human reliability assessment and expert judgment as well as simulation could help perfect the reliability on safety and environmental risk study for inland water ways [8].

Conclusion

System level damage estimation modeling of consequence in risk analysis is important. Hybrid use of use deterministic using first principle characteristics of the system with stochastic process give better reliability for the system design. Associated risks relating to system level consequence has been modeled for Langat River from River physical system behavior and stochastic process. The validated result is useful for limit definition for preventive safety and environmental risk has been presented. Generated risk graph have been used to simulate real time risk in the waterways for relevant decision support the respective result has been validated statistically.

Implications of quantifying cost on benefit attached to waterways as part of decision support. Damage estimation does have some degree of linear relationship with the risks to people and the environment, getting their actual data about damage is hard on this case, thus interpolation of has been employed to generate resulting damage. Risk measurement can further be reliable by determining risk control option through sustainability balance between environmental, economic and safety aspect of IWTS. Thus, it is important to use caution when comparing accident rates across ports and over time because of the differences in reporting criteria.

ALARP comparison show that Langat River is risk is not appalling yet; risk graph is at the lower portion of ALARP. Accident frequency is of 3.8E-5 and consequence energy of 31 MJ, resulting to length of collapse of 9.3m. For a River with such a low traffic, the risk is could conservatively consider high.Incorporation ofadvantage from traffic improvement like implementation of Traffic Separation Scheme (TSS), Vessel Traffic System (VTS), Automatic Identification System (AIS), better training, International Safety Management (ISM) in the risk process could achieve reduction in risk of the channel, real-time environmental information about environmental conditions, including currents, tide levels, winds, transit parameters and improvement against other channel complexity, are useful in sustainability balance work for waterways developments.

Appendix: Nomenclature

Nm – Number ship movement
W – Width of fairway
B2 – Mean beam of subject ship (m)
V1 – Mean speed of meeting ship (Knot)
Ps – Traffic density of meeting ship (ship/nm^2)
Pn – Traffic density
Pi – Impact probability
Th -head- on
To-Overtaking
Tc-Crossing
Ts - specific angle
Tc - Circular
Tr -Random
Ea – Consequence energy
Ni – Expected number of impact
Pa –Probability of accident
Fa =Na Expected number of collision per year
Lp – Length of penetration
Vc –Volume of collapse
Df- Damage function

3. Environmental Risk and Reliability for Sustainable Dredging

Abstract

Dredging work and placement leads to changes to the environment. Environmental impact assessment has been employed to address these changes. Risk assessment which rarely covers large part of uncertainty associated with dredging work is captured in EIA. EIA focus on fixed and inflexible standards which have led to post dredging failures. This makes it necessary to do critical and dependability scientific risk analysis that quantitatively determine whether the changes are serious or irreversible. This paper discuss the new internationally recognized philosophy of risk analysis or formal and system risk based design that provide opportunity to focus on real concern of the dredging project. The paper will discuss case study of failed project based on conventional EIA and best practice performance of systemic risk base design approach.

Keywords: Environment; Dredge; Port, Risk; Relaibility; Safety;

Introduction

Dredging is process of digging under water for purpose to maintain the depth in navigation channels. Dredging is required to develop and maintain navigation infrastructure, reclamation, maintenance of river flow, beach nourishment, and environmental remediation of contaminated sediments. Study on environmental impact of dredging is not new and recently there is concerned about balance between the need to dredge, economic viability, social technical approval and adequate environmental protection can be challenge. Various methods has been implemented for management of dredging activities, but choose in the best practice approach is also a bog challenge that require high level of understanding of the technical and economical aspects of the dredging process. Input from ecological experts and dredging specialists. Community participation from port authorities, regulatory agencies, the dredging industry and non-governmental organisations such as environmentalists and private sector consultancies.

The Need for and dredging requirement: Dredging is the excavation, lifting and transport of underwater sediments and soils for the construction and maintenance of ports and waterways, dikes and other infrastructures for reclamation, maintenance of river flow, beach nourishment, to extract mineral resources, particularly sand and gravel, for use for example in the construction industry, and for the environmental remediation of contaminated sediments.

Globally, many hundreds of millions of cubic meters (m^3) of sediments are dredged annually with most of this volume being handled in coastal areas. A portion of this total represents capital dredging which involves the excavation of sediments to create ports, harbors and navigable waterways. Maintenance dredging sustains sufficient water depths for safe navigation by periodic removal of sediment accumulated due to natural and human-induced sedimentation. Maintenance dredging may vary from an almost continuous activity throughout the year to an infrequent activity occurring only once every few years. Dredging activities offer social, economic and environmental benefits to the whole community. Hydrography chart and bathymetric map are used as guidance to vision of discrete bottom of water. Vigilant is requiring for the bottom as the, they are proned to sudden change leading to shoaling due to flood or drought. Survey of a navigation channel to locate dredging area done through drawing of isolines or lines connecting points of equal depth on the map so that captains and ships pilots can get an idea of the hills and valleys underwater [28,29].

Remote sensing equipment is used by hydrographers on top of the water of the water to see the bottom of the channel. Isoline are drowned based on statistical data record for accuracy and reducing risk of missing important underwater features like rocks or shoals. Dredgers: dredger is a machine that scoops or sucks sediments from under the water. There are a few different types of dredgers, the three main types of dredges are mechanical dredges, hydraulic dredges and airlift dredges. Mechanical dredges are often used in areas protected from waves and sea swells. They work well around docks and shallow channels, but not usually in the ocean. Hydraulic dredges work by sucking a mixture of dredged material and water from the channel bottom. There are two main types of hydraulic dredges the cuter head pipeline dredge and the hopper dredges. Airlift dredges are special use dredges that raise material from the bottom of the waterway by air pressure. Split hull hopper dredges are self-powered, so they can move to the dredging and disposal site by themselves. Figure 46 shows typical hydrographic survey of a channel.

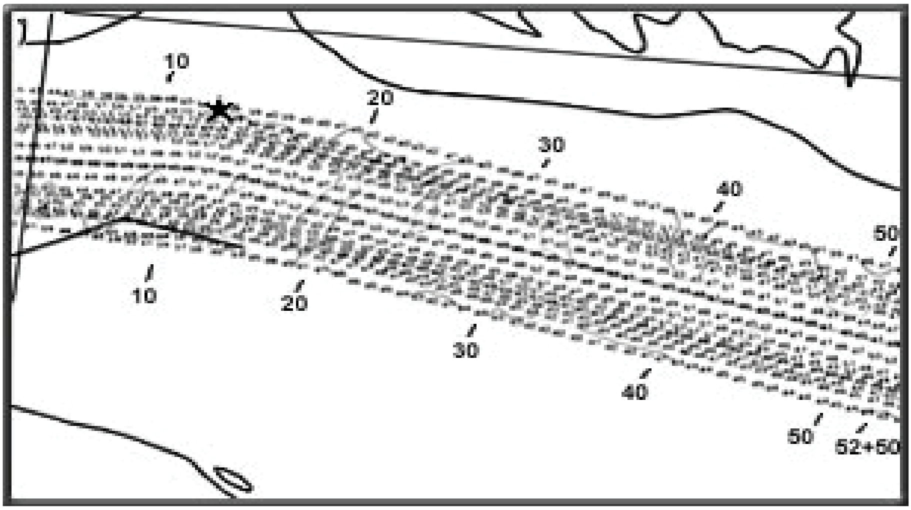


Figure 46: Typical hydrography survey channel condition survey for a channel, 53 m deep, the survey lines are at 50-foot intervals. Shaded areas are shoals.

Dredge material: Dredging is necessary to maintain waterways channel. Nearly 400 million cubic yards of material is dredged each year. Consequently, about 400 million cubic yards of material must be placed in approved disposal sites or else used for another environmentally acceptable purpose. Sustainable disposal of dredge material is very imperative as it ends up saving a lot of money and maintains reliability and efficiency use of resources advantage of sustainable beneficial disposal are [29,30]:

- Cost saving on money spent on finding and managing disposal sites.
- It avoids habitat and ecological impacts that disposal may cause.
- It saves capacity in existing disposal sites.
- It can be a low-cost alternative to purchasing expensive fill for construction projects.
- It can be used to enhance or restore habitat.

Environmental requirement of dredging project: The tendering of a dredging contract typically occurs after a full engineering design has been completed (i.e. after the planning and design phase). However, for other types of contracting mechanisms (e.g., design-build), the tendering of contract may occur early in the overall project process, thus requiring the Contractor to perform much of the evaluation and design work himself. Table 24 shows phases of dredging project and the risk control components.

Project Phase	Planning and design	Construction	Post construction
Impact	Need for dredging is translated into project design. Physical and biological impacts will depend on project specification.	Project construction will cause temporary or permanents physical change, Advert effect should be mitigated through best practice method	Physical change may result to long term environmental effects that should be mitigated by appropriate project design, planning and execution
Scope	Functional requirements, Conceptual design, Potential environmental impacts, and Final design and specifications	Tendering and contract award, Construction methods and equipments selection, Monitoring and feedback	Infrastructures in service and their may have additional mode of impact, Long term monitoring and feedback may be needed to evaluate RCO

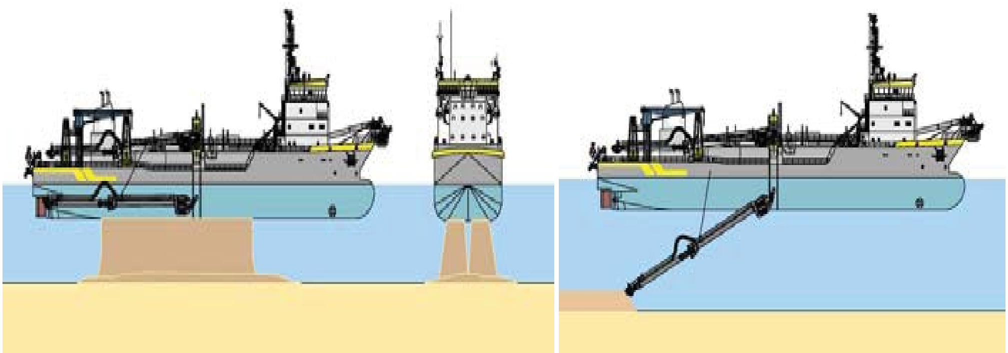
Environmental component	Planning and design decision, RCO to prevent or reduce environmental impact if of the whole project	Construction decision, RCO to prevent environment impact cause by physical change	Certain RCO may apply to mitigation of future impacts

Table 24: Dredging project phases and risk components.

The planning and design phase begins with defining overall functional requirements to meet the project objectives. This involves evaluating potential environmental impacts and any regulatory constraints, and concludes with preparing projects specifications. The planning and design phase is used to identify risk areas and risk control option in advance to help protect the environment during dredging, transport and disposal activities and subsequent monitoring and possible remedial actions. Elements of project formulation include:

- Functional Requirements
- Conceptual Design
- Regulatory Framework
- Baseline Environment
- Stakeholder Input
- Potential impact Review the baseline condition as a consequence of construction and post-project activities.
- Environmental Impact Assessment (EIA)
- Risk control option
- Prepare Final Project Design and Specifications

Afinal design addresses all major elements of the project: engineering design, environmental management, construction sequencing, and construction management. The specification's level of detail will depend on the type of contract, thecomplexity of the project, and the experience with dredging of both the project proponent and contractor(s). Figure 47 shows example operational disposal control measure to limit impact of dredge disposal.



a. b.

Figure 47: a. uncontrolled disposal, b. control disposal (PIANC).

It is important to integrate risk control option that have been evaluated in the environmental review process to ensure that the desired balance between minimizing potential environmental impacts and constraints on construction is achieved. Additional environmental review may be required to establish that any residual risk, or actual impact, is acceptable Risk control option must be based on a clear definition of the project's technical and regulatory requirements. Studies conducted during the EIA or project planning, as well as information from regulators and stakeholders can contribute technical information for informed risk control option including [29,31]:

Sediment characterization (e.g., grain size distribution, level of contamination, etc.)

Bathymetric/topographic surveys with design profiles, which establishes the volume of sediment to be dredged; An understanding of hydraulic/hydrodynamic/oceanographic conditions that may restrict operations; The destination or final use of the dredged material, including placement options and locations; The environmental functions and value of the area to be dredged, establishing environmental boundary conditions; The environmental value of dredged material management areas (e.g., placement in confined or unconfined areas or beneficial use options) Existing site uses (e.g., navigation, recreational use, commercial fishing, quality of life impacts (air, noise, light) to establish reasonable operational measures;

Legal conditions: Environmental aspects related to future use and maintenance of the project's post construction condition should consider the areas of facility operations, future maintenance, long-term monitoring. During the construction phase, the contractor assumes primary responsibility for meeting the requirements of the project specifications, including meeting permit and contractual environmental conditions and implementation of risk control options. Major steps in the construction phase include: Figure 48

Tendering and Contract Award

Contractor Defines Construction Methods and Selects Equipment

Project Execution: Risk control option should based on best practice

Figure 48: Post dredging impact in Kuala Terengganu.

Environmental risk requirements of dredging project: Risk analysis in a dredging project, including taking into account adherence to the Precautionary Principle. It involves methods for assessing the significance of the likely impacts and essential environmental characteristics that require consideration during both the planning and implementation phases and the mechanisms whereby impacts can occurs Figure 49.

Qualitative based environmental impact assessment: Dredging and disposal of dredged material have many potential implications for the environment, like disturbance of benthic invertebrates, disruption of their

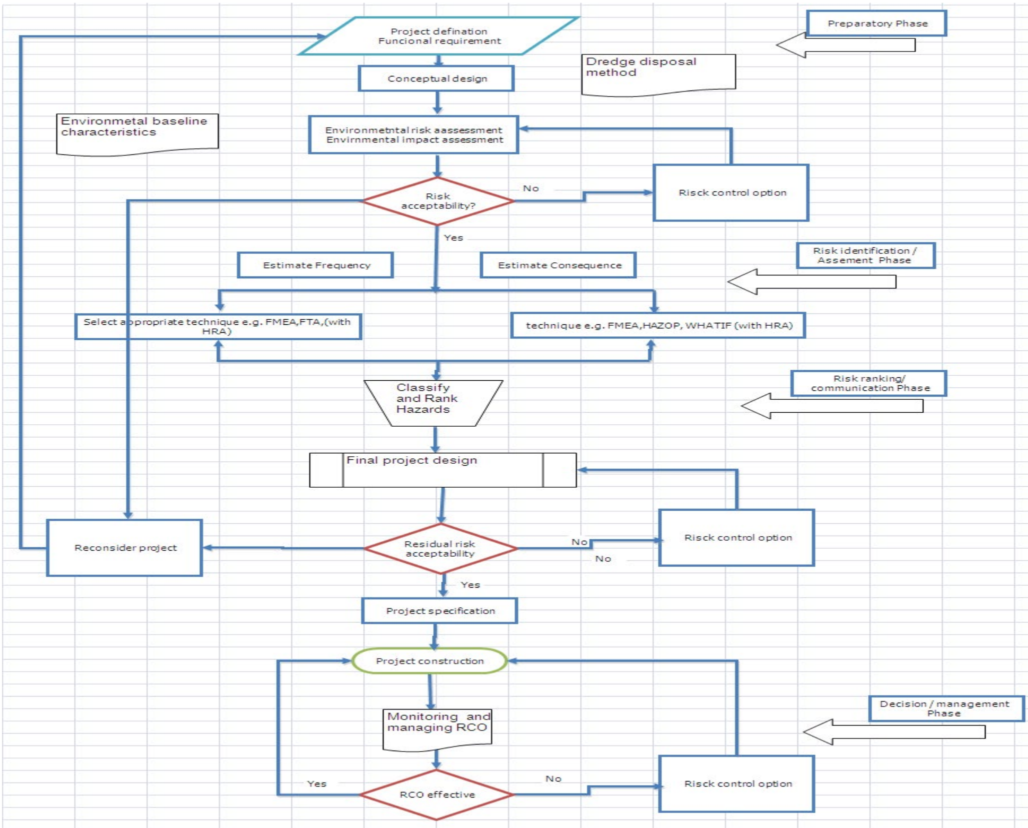


Figure 49: Risk based model for dredging projecthabitats and direct mortality.

The scale of these impacts depends on several factors, including the magnitude, duration, frequency and methodology of the dredging activity and the sensitivity of the affected environment. The need for RCO to reduce the effects of dredging, transport and placement depends on the results of the impact assessment process and effectiveness to meet goal of protecting sensitive environmental resources, maintenance of healthy ecosystems and ensuring sustainable development and exploitation of resources.

Understanding the environments in which dredging and dredged material placement occur is a prerequisite of prudent decision making for environmental protection. A thorough knowledge of baseline conditions is needed so that a dredging project's environmental effects can be assessed properly and monitored against an agreed baseline. The baseline data must address natural variations, seasonal patterns and longer term trends to provide a context for determining whether a change is the result of dredging or not. As a minimum, characterization of the potentially affected environment should consist of recent surveys (performed within the last three years) and studies of the relevant environmental attributes.

For reliability the studies must be conducted by qualified scientific and engineering personnel using accepted methods. The boundary includes the physiographic, hydrologic, ecologic, social, and political boundaries of the project areas. In general, the following types of data are required for characterization of the dredging and placement sites, the transport corridor and the areas around these sites, which could be indirectly affected, to adequately address the range of management options [32,33]:

- Bathymetric and adjacent topographic data
- Habitat and species distribution
- Resources such as fish populations, shellfish beds, oil and gas fields, aggregate mining and spawning grounds
- Physical and chemical nature of sediments
- Water quality
- Hydrodynamic data
- Cultural resources, including archaeological and anthropological conditions
- Human demography and land use characteristics
- Users of the environmental resources, such as commercial, recreational, and subsistence fisheries
- Navigation routes and
- Services in the project area, such as pipelines and cables.

In addition, it is necessary to take into account any cumulative impacts. Certain ongoing activities, such as fisheries and navigation, could have impacts that in combination with the proposed dredging result in more significant effects than would result from the project activities alone. This information is generally included in the impact assessment.

Between environmental risk assessment and environmental impact assessment

In practice, different approach is used to evaluate and measure the environmental impacts of a dredging project. ERA is defined as the examination of risks resulting from the technology that threaten ecosystems, animals and people. There are three main types of ERA: human health, ecological, and applied industrial risk assessment. The origin of ERA is the assessment of risks in the industry. Then, the same approach was applied in a broader scale for assessing the risks of the release of chemicals posed to human health. The more recently developed ecological risk assessment follows the same approach as human health ERA, but extending the assessed end-points to species other than human beings.

A conventional approach of an environmental risk assessment begins with the problem formulation and the identification of the hazard (or hazards). Then, the possible ways of release of the hazard are estimated and the exposure of those chosen target species is assessed. The final steps are the consequence assessment and the estimation of the risk. Some of the steps require the use of models (e.g. the assessment of the release and the exposure) and the outcome is usually a quantitative assessment. It should be noted that many choices have to be done in the design of the risk assessment and thus the definition and method used in each of them will be of importance to the final outcome [34].

It has also been common that human health and ecological ERA are normally applied for assessing the risks regarding the release of one single chemical. They would need to be adapted for assessing the impacts of dredging operations, where more than one chemical might be released together. It is cleared that the consequences of dredging might be broader than the release of chemicals. Another group of tools widely used at present is Environmental Impact Assessment (EIA).

There are also several methodologies for performing an EIA. They depend on the assessed activity, and of course the way the final impacts are presented and aggregated. The effects considered in an EIA are very wide, from pollution effects to a wider range of ecological effects, and it is often a statutory requirement under holistic doctrine to consider all possible effects, including economic, social and political.

The difference between ERA and EIA is that the later do not treat risks as probabilities. Generally the potential impacts are predicted, and assessed quantitatively or qualitatively. However, it also uses models requires for making many decisions in the design of the assessment, which could influence the final result. Any evaluation of the impacts of a certain project has to face difficulties and uncertainties in part due to the scientific uncertainties involved but in part due to the decisions to be made for framing and defining the problem. The impact assessment will have to specify the range of species to include and thus get entangled in nontrivial normative (ethical, ecological and economic) issues.

Risk based design and precautionary principle: The Communication from the Commission of the European Communities on the precautionary principle (Commission of the European Communities) states that the Precautionary Principle should be applied within a structured approach to the analysis of risk. As outlined above, this comprises three elements: risk assessment, Risk analysis, risk management and risk communication. The Precautionary Principle is particularly relevant as an instrument in the management of risk.

In the context of dredging projects it can be stated that because of great natural variability there will often be a lack of full scientific certainty about the scales of potential impacts. In accordance with the Precautionary Principle decision to forego a project should be a last resort following exhaustive consideration of all reasonable RCO and reaching a conclusion that adequate environmental protection could not be achieved. Prohibiting dredging may ensure that no impacts occur, but may also generate high risk to human safety (e.g., lack of removal of shoals that pose navigation hazards) or result in lost commerce and harm to the economy. The RCO should be selected such that clear, defined, and ideally quantitative thresholds of protection can be achieved (e.g. to control measures of suspended sediment within a specified concentration/duration range). Figure 50 shows typical system risk components [35,36].

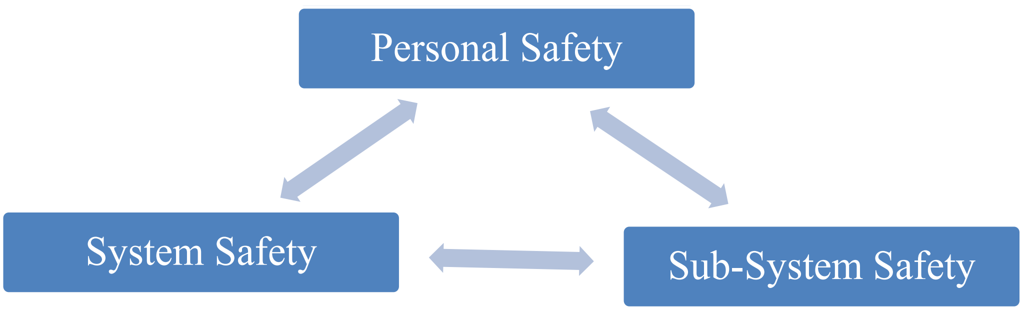


Figure 50: Components of risk assessment and analysis.

The approach to risk assessment begins with risk analysis, a systematic process for answering the three questions posed at the beginning of this chapter: What can go wrong? How likely is it? What are the impacts? The formal definition of a risk analysis proceeds from these simple questions, where a particular answer is Si, a particular scenario; pi, the likelihood of that scenario; and Ci, the associated consequences. See Figure 51.

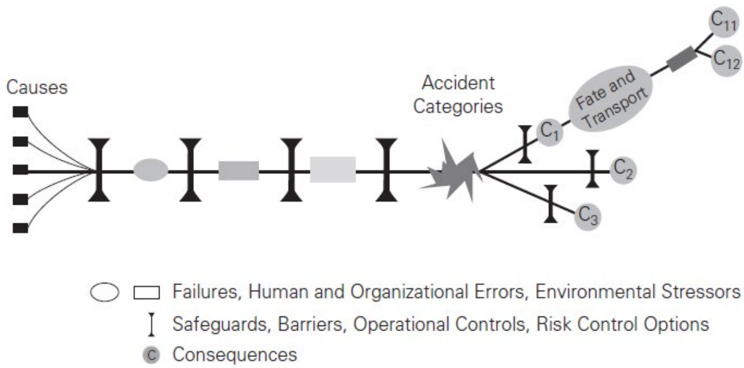


Figure 51: Risk based method.

Thus cost of environmental sustainability is not cheap, but whenever we compare the benefit and longtime reliability with the cost, there is no doubt that the later will supersede the earlier. Dedication on scientific analysis, environmental assessment work, never get attention in the past like to today. The fact that everything stays with us, is recently calling for philosophy for minimum used of toxic material in our daily activities. Yes, scientific work or test required prudent analysis over time but once we have information we should restrain under the doctrine that prevention is better than cure.

Work on environmental issue has always involved dispute because of impacts analysis. Global climate Change might be regarded as a primary example where this strong interlinkage between science and policy making is broadly acknowledged, Social science studies have shown how the production of scientific knowledge played a crucial part in the rise of climate change as a topic of worldwide interest and to the political arena while, on the other hand, knowledge and research on climate change issues is influenced by social factors

In most countries, the majority of dredged material is placed at sea. Land disposal options are normally much more expensive therefore, they are applied only when either transport costs to sea are inhibitory, or beneficial use is not an option, or the material is too contaminated. In order to meet sustainability requirement the following describe 3 case studies where beneficial work in dredging are translated to cost [37,38].

On environmental sustainability According to US green port project, 2001, case study on Boston port navigation improvement project done in the US dredging and construction project use mitigation like Surface sediments contaminated with metals, PAHs, PCB, and other organics, Channels were over-dredged by 20 ft. Contaminated material was placed on barge and deposited into over-dredged in channel disposal cells and covered with 3 ft. clean material, All clean material deposited in Mass Bay Disposal Site.

Another case done in port of los Angelis use copper treatment by developing onsite system to treat copper contaminated marine sediments, Pilot study dredged, treated and disposed of 100 tons of contaminated sediment, Full-scale project cleaned up 21,000 cubic yards of contaminated sediment, Saved $1.5 million in cleanup costs over alternative.

Studies done in Europe also confirm use of processing plant for dredge material. Also regional sediment management program done by compiled various methodologies to reduce shoaling.

Reliability and decision support framework: Various studies have been carried out to find the best hybrid supply for given areas. Results from specific studies cannot be easily applied to other situations due to area-specific resources and energy use profiles and environmental differences. Energy supply system, with a large percentage of renewable resources varies with the size and type of area, climate, location, typical demand profiles, and available renewable resource. A decision support framework is required in order to aid the design of future renewable energy supply systems, effectively manage transitional periods, and encourages and advance state of the art deployment as systems become more economically desirable. The DSS could involve the technical feasibility of possible renewable energy supply systems, economic and political issues.

Reliability based DSS can facilitate possible supply scenarios to be quickly and easily tried, to see how well the demands for electricity, heat and transport for any given area can be matched with the outputs of a wide variety of possible generation methods. This includes the generation of electricity from intermittent hybrid sources. DSS framework provide the appropriate type and sizing of spinning reserve, fuel production and energy storage to be ascertained, and support the analysis of supplies and demands for an area of any type and geographical location, to allow potential renewable energy provision on the small to medium scale to be analyzed. DSS can provide energy provision for port and help guide the transition towards higher percentage sustainable energy provision in larger areas. The hybrid configuration of how the total energy needs of an area may be met in a sustainable manner, the problems and benefits associated with these, and the ways in which they may be used together to form reliable and efficient energy supply systems. The applicability and relevance of the decision support framework are shown through the use of a can simulate case study of the complex nature of sustainable energy supply system design.

Regulatory requirement and assessment: The current legal requirements have been developed based on reactive approach which leads to system failure. Reactive approach is not suitable for introduction of new technology of modern power generation systems. This call for alternative philosophy to the assessment of new power generation technologies together with associated equipment and systems from safety and reliability considerations, such system required analysis of system capability and regulatory capability. System based approaches for regulatory assessment is detailed under goal based design as shown in figure.

IMO has embraced the use of goal based standards for ship construction and this process can be equally well applied to machinery power plants. Figure 52 illustrates the goal based regulatory framework for new ship construction that could be readily adapted for marine system.

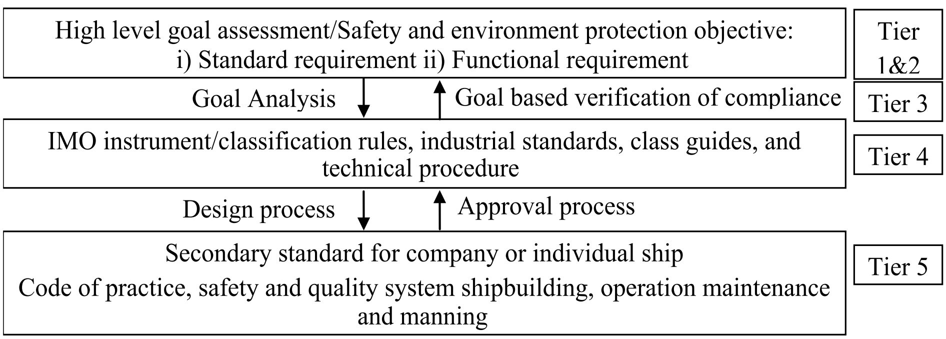


Figure 52: Components of level goal standard assessment.

Legal framework for dredging: The most important international agreements regarding dredging are the London Convention 10, issued in 1972 and reviewed in the 1996 Protocol

11 and the OSPAR Convention 12 from 1992. IMO also unveil Formal safety assessment for marine system. These international agreements establish frameworks within which the contracting countries are obliged to operate with respect to their handling of materials destined for placement in the sea. However, these Conventions do not include regulations of the dredging operations per se, which are mainly established at the national level nor for the conditions of disposal of in land.Convention for the prevention of marine pollution by dumping of wastes and other matter [39].

A review of the Convention began in 1993 and was completed in 1996 with the acceptance of The 1996 Protocol to the London Convention. The 1996 Protocol has not yet come into force as it has not yet been ratified by a sufficient number of countries (19 out of 26). Conventions for the Protection of the Marine Environment of the North-East Atlantic [40]. On the other hand, dredging activities are subject to national regulations, which can vary very much among the countries. In some cases there is a specific directive regarding dredging in Malaysia the royal Malaysia navy regulate the dredging. Thus they are other agencies but there is not integration for effectiveness of the system (personal communication).

Quantitative and formal system engineering based risk analysis: Risk is generally understood as an expression of the quantified link between an environmental hazard or stressor and the potential negative consequences it may have on targets or receptors. When discussing risk the types of stressors as well as the targets of interest must be specified. Thus project risk can be distinguished from engineering risk, and environmental risk. But, in practice it may be very difficult to establish a quantifiable relationship between hazard and target response because of the many uncertainties in the cause effect chain and the dynamic nature of aquatic ecosystems. Risk analysis provides a means to accommodate these uncertainties. Formal risk assessment procedures have not been adopted by many regulatory agencies or they have been applied mainly to dredging of contaminated sediments. Typically risk assessment takes the form of professional judgment based on the experience and expertise of parties engaged in project co-ordination [41].

Risk analysis provides an opportunity to focus on the real concerns of a project, instead of relying on fixed and inflexible standards such as threshold levels for contaminants or fixed percentages of allowable overflow of a dredger. For the purpose of this report, risk assessment is mainly captured in the EIA, whereas risk management takes the form of best management practice determination. Risk evaluation is the path from the scientific system based quantitative risk analysis is the internationally recognized best practice and modest concept of risk analysis. Table 25 shows components of risk analysis.

Components	Purpose / Process
Risk analysis	Involve the overall process of risk assessment and risk management, including screening and scoping
Risk assessment	Involve qualitative process of identifying risk potential to quantitative risk characterization
Risk screening	Involve the specification and setup of a general framework for managing risk
Risk evaluation	Involve: Scientific evaluation of risks through use of stochastic process Public/political evaluation of risks
Risk management	Involve: Process of identifying and selecting measures Procedures for implementation and evaluation of measures

Table 25: Components S.

An outline about risk assessment and the application of risk informed decision making can be found in Bridges. This document does not address the scientific methods to evaluate the human health and ecological risks of a project. In this case other guidance, like the PIANC Working Group Envicom 10 report on Environmental Risk Assessment of Dredging and Disposal Operations, should be reviewed and properly qualified professionals engaged to perform the necessary work. Analysis tools that now gaining general acceptance in the marine industry is Failure Mode and Effects Analysis (FMEA). The adoption of analysis tools requires a structure and the use of agreed standards. The use of analysis tools must also recognize lessons learnt from past incidents and experience and it is vital that the background to existing requirements stemming from rules are understood. Consistent with the current assessment philosophy, there needs to be two tenets to the process safety and dependability. A safety analysis for a hybrid power generation system and its installation on board a ship could use a hazard assessment process such as outlined in Figure 53. The hazard assessment should review all stages of a systems life cycle from design to disposal.

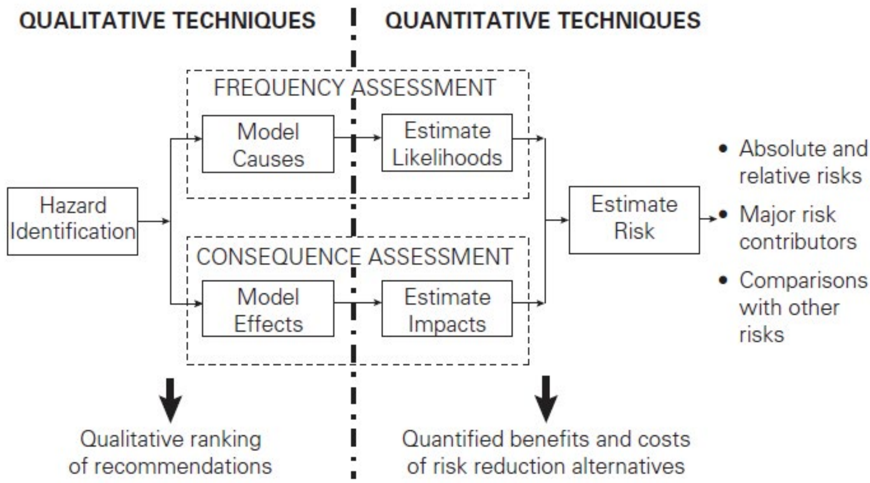


Figure 53: Components of risk and reliability analysis.

Figure 53 shows the components of risk assessment and analysis. The analysis leads to risk curve or risk profile. The risk curve is developed from the complete set of risk triplets. Table 26 shows elementsof risk analysis. The fourth column is included showing the cumulative probability, Pi (uppercase P), as shown. When the points <Ci, Pi> are plotted, the result is the staircase function. The staircase function can be considered as discrete approximation of a nearly continuous reality. If a smooth curve is drawn through the staircase, that curve can be regarded as representing the actual risk, and it is the risk curve or risk profile that tells much about the reliability of the system. Combination of qualitative and quantitative analyses is advised to for risk estimates of complex and dynamic system.

Scenario	Probability	Consequence	Cumulative Probability
S1	P1	C1	P1=P1+P2
S2	P2	C2	P2=P3+P2
Si	Pi	Ci	Pi=Pi+3+Pi
Sn+1	Pn+1	Cn+1	Pn-1=Pn+Pn+1
Sn	Pn	Cn	Pn=Pn

Table 26: Components of risk and reliability analysis.

The analysis that describes and quantifies every scenario, the risk estimation of the triplets can be transformed into risk curve or risk matrix of frequency versus consequences that is shown in Figure 54.

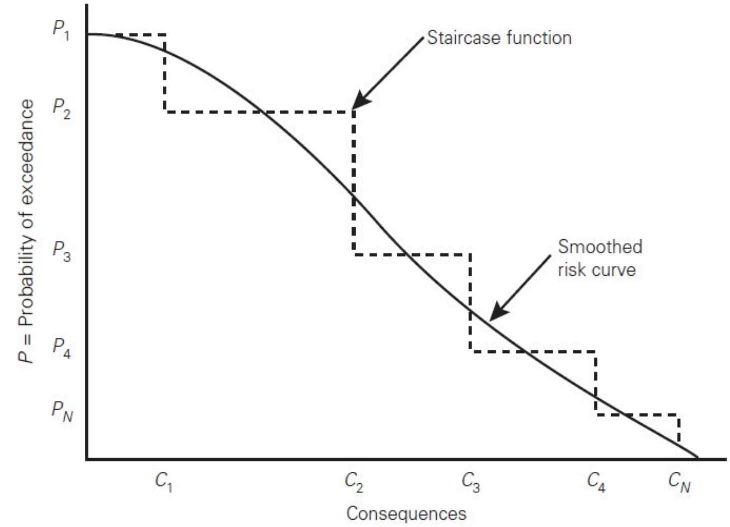


Figure 54: Stair case risk curve.

Frequency of Occurrence (or Likelihood)	Consequences (Severity of Accident)				
	Incidental (1)	Minor (2)	Serious (3)	Major (4)	Catastrophic (5)
Frequent (5)	M	H	VH	VH	VH
Occasional (4)	M	M	H	Risk without measure	VH
Seldom (3)	L	M	H	H	VH
Remote (2)	L	L	Risk after measure	H	H
Unlikely (1)	L	L	M	M	H

Figure 55: Risk priority matrix.

L = low risk; M = moderate risk; H = high risk; VH = very high risk.

The design concept needs to address the marine environment in terms of those imposed on the power plant and those that are internally controlled. It is also necessary to address the effects of fire, flooding, equipment failure and the capability of personnel required to operate the system. In carrying out a hazard assessment it is vital that there are clearly defined objectives in terms of what is to be demonstrated. The assessment should address the consequence of a hazard and possible effect on the system, its subsystems, personnel and the environment. An assessment for reliability and availability of a hybrid power generation system and its installation in a ship could use a FMEA tool. An effective FMEA needs a structured approach with clearly defined objectives

The assessment analysis processes for safety and reliability need to identify defined objectives under system functionality and capability matching. These two issues are concerned with system performance rather than compliance with a prescriptive requirement in a standard. The importance of performance and integration of systems that are related to safety and reliability is now recognized and the assessment tools now available offer such means. Formal Safety Assessment (FSA) is recognized by the IMO as being an important part of a process for developing requirements for marine regulations. IMO has approved Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (MSC/Circ.1023/MEPC/ Circ.392). Further reliability and optimization can be done by using stochastic and simulation tools [35,42].

Uncertainties and risk in dredging projects

The physical and biological characteristics of aquatic environments vary both spatially and temporally. Therefore characterizing these environments and assessing impacts and risk will always involve some uncertainty. This requires the need for basic understanding of how marine and the ecosystems function and how natural events and anthropogenic activities affect these functions. In the ideal situation, all environmental risks associated with a dredging project would be quantifiable, making the need for specific management practices clear. In reality, dredging can potentially affect diverse assemblages of organisms or their habitats on both spatial and temporal scales. Because the scales of the interactions between organisms and the dredging process are difficult to determine, often the consequences of a project are largely speculative. Some degree of uncertainty will therefore always be present indecisions regarding the need for special management practices to protect the environment.

It is important to recognize that even with extensive baseline data and input from qualified professionals, an element of uncertainty will always be associated with the results of an environmental assessment, simply due to the dynamic nature of marine and freshwater environments and the complexity of stressors and drivers apart from anthropogenic influences. Effects of dredging operations have to be seen against the background of similar natural effects. Figure 56 shows that in a typical dredging project the risk assessment is made after the preparation of the Conceptual Design. If at this stage it proves that the environmental risks are such that they cannot be mitigated by implementation of the appropriate best practice then the project should be reconsidered. This means that functional requirements will need to be redefined followed by a revision of the Conceptual Design.

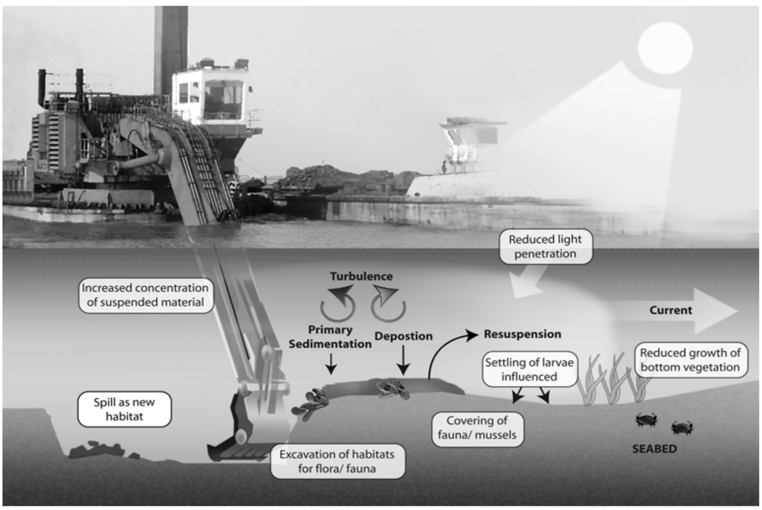


Figure 56: Possible Environmental Effects of Dredging [38].

In the process of risk work, newer refined RCOs may become necessary during the process of risk management. During the preparation of the final project design it is essential to establish the degree of residual risk. Figure 57 shows potential impact to marine aquatic.

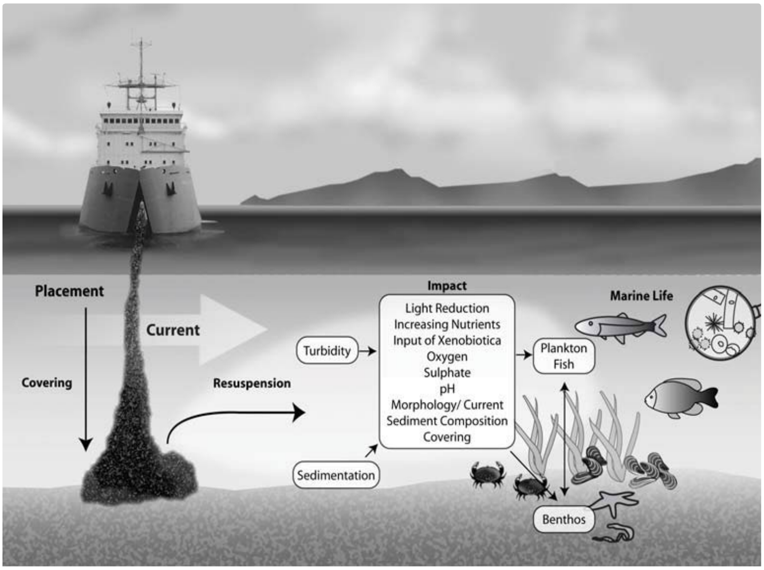


Figure 57: Possible Environmental Effects of disposal [38].

Potential Physical Changes and Environmental Impacts from Dredging and Disposal of Dredged Material

Below water, the sound from the dredge vessel could have environmental effects such as interfering with fish behavior, possibly leading to disturbed migratory routes, although fish might easily avoid temporarily disturbed areas without consequence. Other potential environmental effects not directly related to dredging but associated with the presence of the dredger include spills of oil and fuel, exhaust emissions, and the possible introduction of invasive species via the release of ballast water.One of the less understood areas of concern is the impact of sediment released into the aquatic environment that may occur at any of the stages from excavation to placement. A high concentration of sand in suspension will have very low turbidity while a relatively low concentration of fine silt or clay in suspension will have a high turbidity. Also sediment effect on the flora and fauna, concentration, the turbidity, the total amount of loss of sediments or the spatial distribution of a sediment plume are other impacts.

Sediment re-suspended in the water column in high concentrations can directly lead to physical abrasion of, for example, filter-feeding organs or gill membranes of fish and shellfish. Indirectly, if present for sufficient duration, high turbidity (i.e. reduced light penetration), can result in decreased growth potential or total loss of submerged aquatic vegetation. The resuspension of sediments can also release toxic chemicals or nutrients such as phosphates and nitrates, which may increase the atrophic status of the system (this reinforces the need for appropriate sediment characterization). Release of anaerobic sediment and organic matter in high concentrations mayin some cases deplete the dissolved oxygen. Subsequent sedimentation around the dredging site can smother benthic flora and fauna or compromise habitat quality.

Spatial and temporal scales of effects: The environmental effects vary spatially and temporally from project to project. When the effects are considered to have a significant adverse impact it is necessary to investigate means to reduce or mitigate them. The significance of the environmental effects depends on site-specific factors that govern the vulnerability and sensitivity of environmental resources in the project area. When the sediment being moved is chemically contaminated, the need for environmental protection is generally recognized by all stakeholders.

Complexity with respect to uncertainty has made necessity for several efforts to find tools for the assessment and management of different types of uncertainty. As mentioned before, the word uncertainty is used in many different situations for expressing a lack of certain, clear knowledge for taking a decision. Uncertainty is any departure from the unachievable ideal of complete determinism. In the case presented here, uncertainty signifies that is not possible to provide a unique, undisputable, objective assessment of a certain action (for example an environmental risk assessment of the dredging). However, depending on the actor (e.g. the modeller, the policy maker, or stakeholders), the perception of the nature, kind, object and meaning of uncertainty can be very different. This will be clear when presenting the perception of uncertainty of the stake holders involved in the case. Nevertheless, the simple definition presented above gets more complicated when trying to describe the sources, or the sorts or dimensions of uncertainty.

Typology approaches adopted for characterization and assessment of uncertainty by this group focus on uncertainties encountered from the point of view of the modeler that assesses policy makers (which they call model based decision support). Therefore, their proposal aims to be useful for expressing the uncertainty involved in the use of models, perhaps rather than expressing uncertainty from the point of view of the policy makers or stakeholders. The typology is based in the distinction of three dimensions of uncertainty:

- The location of uncertainty (where within the model);
- The level of uncertainty (from deterministic knowledge to total ignorance) and,
- The nature of uncertainty (whether the uncertainty is due to the imperfection of our knowledge or is due to the inherent variability of the phenomena being described).

Risk communication and management: Parties involved in a dredging project view the process differently depending on their individual perceptions of these risks and rewards, as well as their individual tolerance of the perceived risk. In this sense there may be several types of risk in a project. For the proponent the consequences of failure of the whole project may be very severe and will usually be measured in economical terms. For an environmentalist the potential effects on the environment may be recognized as the highest priority risk. Communication is an essential component of sharing concerns and identifying means to mitigate them to the fullest extent reasonably possible. During the risk analysis, it is important to balance the identified environmental effects and risks against the economic and social consequences of the project. Figure 58 shows stake holder involvement in dredging decision.

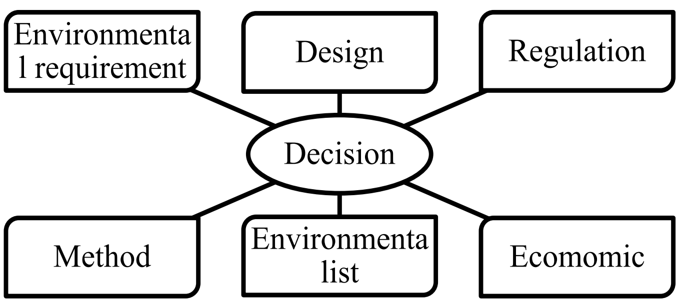


Figure 58: Stake holder involvement in dredging decision.

Complete and transparent communications are therefore essential throughout the process from beginning to end. This refers to all parties involved. Communication should address uncertainties and natural variability in the environment. Seldom does an actual project present a clear choice between unbiased, neutral, and generally accepted options. Rather, the choice among options is frequently driven by values and perceptions. This tension can best be reduced through open lines of communication that include:

- A transparent process
- Outreach that begins during the earliest possible stage of the project and continues throughout all phases
- An open and honest process
- Proactive engagement of local and/or regional media, because their influence on public opinion can be large.

Risk perception is very much influenced by the social, political and historical contexts. Environmental Protection Agency's (USEPA) can be found giving some generic recommendations. Figure 59 shows expected impact in dredging project. The figure also shows the interrelation ships between physical changes above and below the water and their potential to cause environmental effects. The figure also illustrate physical changes can create multiple environmental effects.

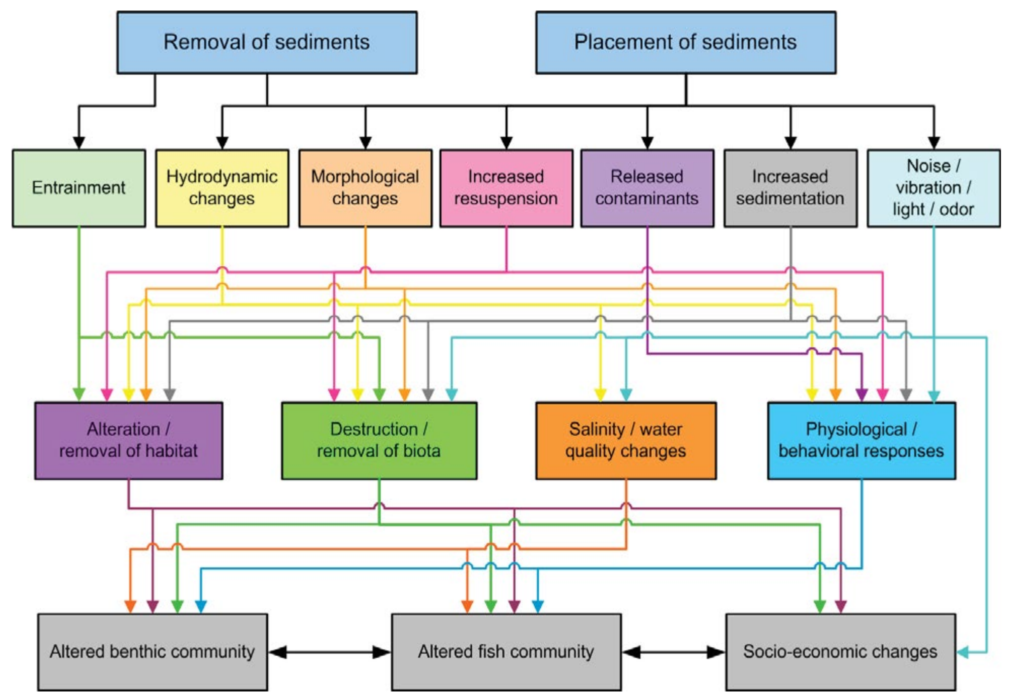


Figure 59: Conceptual Model of Physical Changes and Ecological Effects from Dredging - Related Activities.

Selecting evaluation and risk control option for dredging project: Action might be taken to adjust the monitoring program itself or as a direct response to the monitoring results. Based on the monitoring data, adjustments to the monitoring program could include:

- Reducing the level of monitoring because no effect was observed;
- Continuing with the existing monitoring program to gain further clarification of the response; or
- Expanding the monitoring program to include additional parameters or sites.

So that responding can be quick and effective, it is necessary to establish hierarchy of options to adverse monitoring results. The level of response can be targeted to the receptor and its sensitivity. Options could include:

- Continuing with dredging under the existing regime;
- Modifying the dredging regime to reduce the actual effect on a sensitive parameter;
- Ceasing dredging within an area until further information is gathered;
- Ceasing dredging within an area altogether; or
- Ceasing dredging and implementing recovery measures.

For a monitoring program to be fully effective, it must include a timely communication of results and related actions. Stakeholders should be involved to help build overall program credibility. Risk control options are meant to improve the environmental performance of a dredging project. Some form of environmental evaluation or Environmental Impact Assessment (EIA) is normally required by international conventions. One example is the London Convention, which establishes a framework for the evaluation of placement of dredged material at sea. The Specific Guidelines for Assessment of Dredged Material [29] comprises the following steps:

- Dredged material characterization
- Waste prevention audit and evaluation of disposal options
- Is the material acceptable for marine placement?
- Identify and characterize the placement site;
- Determine potential impacts and prepare impact hypothesis(ies)
- Issue permit
- Implement project and monitor compliance and
- Field monitoring and assessment.
- Within the LC-DMAF guidance it is stated that

Assessment of potential effects should lead to a concise statement of the expected consequences of the sea or land disposal options i.e., the Impact Hypothesis. When applying these Guidelines uncertainties in relation to assessments of impacts on the marine environment will need to be considered and a precautionary approach applied in addressing these uncertainties. Figure 60 shows risk matrix for risk measure of risk based design.

Frequency of Occurrence (or Likelihood)	**Consequences (Severity of Accident)**				
	Incidental (1)	Minor (2)	Serious (3)	Major (4)	Catastrophic (5)
Frequent (5)	M	H	VH	VH	VH
Occasional (4)	M	M	H	Risk without measure	VH
Seldom (3)	L	M	H	H	VH
Remote (2)	L	L	Risk after measure	H	H
Unlikely (1)	L	L	M	M	H

Figure 60: Risk priority matrix.

All dredging and placement projects will cause some changes to the environment. It is therefore necessary to determine whether these can be considered serious and or irreversible. Because adequate information is rarely available to answer these questions with absolute certainty, an evaluation of the relative risk of permanent detriment to the environment is required. Many factors affect this assessment of the general environmental risk including the scale of the project, the natural variability of all of the elements of the system likely to be affected, possible contamination levels, and the timing of the project. Preparation of an EIA involves collaboration among environmental scientists and engineers in consultation with port authorities, dredging companies and often a diverse assemblage of stakeholders. The amount of technical information available will be important but should be used in tandem with the perceptions and knowledge held by the engaged stake holders. Risk evaluation is a value judgment reached by consideration of the total body of evidence offered by all interested parties.

An overview of the selection process is shown in Figure 60, which also shows how the process can be repeated to achieve a project that optimally conforms to acceptable environmental risks. The flow chart shows that there are multiple stages within the process that allow feedback and repetition in order to achieve a project that is in full compliance with acceptable environmental risk. For example, if the application of certain RCO does not reduce the risk to an acceptable level then the project would need to be reevaluated to determine if other alternatives could be used or the project design modified to reduce or remove such unacceptable risks. Feedback loops also occur following the analysis of monitoring results against the required objectives. The effectiveness of the RCO is assessed against the degree of derived protection of the environmental resource and if found to be ineffective then further RCO may be necessary. Monitoring to measure the effectiveness of the selected RCO provides adaptive feedback that can be applied to future projects, and is always a prudent strategy.

These constrains are very important to bear in mind when we think of environmental management at the local or regional level with projects with are used limited time and budget of money. Therefore the lack of knowledge that can be experienced by both managers and citizens in assessing a concrete project may have more to do with limited resources than general scientific ignorance. Benefit-Cost Analysis (BCA) is a tool for organizing information on the relative value of alternative public investments like environmental restoration projects. When the value of all significant benefits and costs can be expressed in monetary terms, the net value (benefits minus costs) of the alternatives under consideration can be computed and used to identify the alternative that yields the greatest increase in public welfare. However, since environmental goods and services are not commonly bought or sold in the marketplace, it can be difficult to express the outputs of an environmental restoration project in monetary terms.

Risk monitoring: It is acknowledged that monitoring can take many forms and fulfill various objectives before, during, and after any dredging and placement project. This document does not provide an exhaustive description of monitoring technology but rather focuses on the role of monitoring as a necessary element in the context of BMP application. In particular, monitoring can be proposed as a management practice in itself or used to assess the effect of other management practices. Monitoring is the first step-in determining whether corrective actions will be necessary to ensure the required outcomes [42,43].

One of the key issues related to any environmental monitoring program is the scope for combining broad monitoring objectives for separate parameters into a single survey. Monitoring programmes can be categorized into three types:

- Surveillance monitoring
- Feedback monitoring
- Compliance monitoring

Formulating a suitable monitoring strategy requires the following elements:

- Targeted objective
- Beeline condition
- Monitoring criteria
- Methodology for measuring change

- Threshold values
- Timely review procedure

Requirements for monitoring are site-specific and based on the findings of the baseline surveys. For example, surveys could be necessary to record:

- The abundance and distribution of species, which is needed to determine
- the rate of species and community recovery within the study area;
- The effect of dredging on seabed morphology;
- The effect of dredging on the concentration of suspended sediments in the water column;
- The type of substrate remaining following dredging;
- Use of the area by fish and
- Actual effects on any sensitive species or communities within the study area.

Sometimes, model studies can be used to determine the appropriate locations for monitoring. Monitoring involves many uncertainties and difficulties that need to be considered. Models are generally not well validated or calibrated and so it is not easy to quantify the results with certainty though they are continually improving. After the monitoring criteria have been selected, the methodology for measuring change against those criteria needs to be determined.

A number of biological, physical, and chemical variables need to be considered when defining a monitoring scheme. The variety of possible effects depends on the Characteristics of the dredging and placement areas and the dredged material itself, therefore, the monitoring programmed sign must be site and case-specific and proportional to the extent of the environmental concern. It is also important to understand the possible causes of the environmental problem to identify the source of the problem. There should be a specific hypothesis that can be tested using easily acquired data.

The monitoring could be in the water column, on the seabed, on land or in the air. It could be physical, chemical, or biological or a combination. Key considerations in establishing the monitoring methodology are summarized below:

The methodology used to monitor environmental effects should be the same as that used to determine the characteristics of the relevant parameter during the baseline survey, to ensure comparability.

The sampling stations should be the same, although there are likely to be fewer stations (e.g., the feature of interest may require a more targeted approach than was adopted for the baseline survey).

For parameters where timing is critical (e.g., benthic and fish sampling), repeat surveys should be undertaken at the same time of year as the baseline survey to ensure that seasonal changes in abundance and distribution do not affect the results.

The frequency of sampling is determined based on the monitoring objectives and criteria. The expected impact is also a factor to consider when determining frequency of sampling. For some parameters (e.g., impacts on geology), changes occur over a long time scale and therefore require less frequent monitoring, possibly post project.

It is important to identify a level above or below which an effect is considered unacceptable, referred to as an environmental threshold. If the monitoring shows that the threshold level is close to being reached then remedial action is required to reduce the level of effect. In the absence of a threshold value, monitoring of many parameters is justified to improve the knowledge base of the particular effect. Timely review of monitoring results is essential to ensure the success of the program. It is recommended that the results of monitoring should be reviewed at times that will allow for meaningful adjustments to the dredging and placement activities.

Conclusions

Dredging provides economic and social benefits for the whole community. However dredging can and often will have an impact on the environment outside of the desired change of say deepening a channel. To assess the significance of these effects an environmental impact study often needs to be undertaken. During such a study, cumulative and in-combination effects should be considered as it is important to place the dredging activity into context with other activities e.g., fisheries, navigation, etc. Previous regulatory work for system design has been prescriptive by nature. Performance based standards that make use of alternative methods of assessment for safety and reliability of component design, manufacture and testing is recommended for hybrid alternative energy system installation.

System failure and carefree of environment in past project poised all field of human endeavor to adopt precautionary principle by providing tools to conduct dredging projects in an environmentally sound manner and design based on comprehensive system based scientific method discussed in this paper. Properly applied the precautionary principle provides incentives to develop better solutions. The paper present structured approach and strives for an objective means of selecting the most appropriate Risk control option for that lead to the best protection of the environment and meet sustainable development requirement. Absolute Reliability of the dredge work can be realized by using predictive statistical tools and the data collected.

4. Risk and Hazard Operability Process of Deep Water Marine System

Abstract

The maritime and offshore industry has made use of the ocean in a very responsible way, the challenged posed by environmental concern in the coastline is evolving new technology and new ways for technological development. In an age so dire to find alternative and sensitive ways to mitigate challenge of global warming, climate changes and its associated impact, maritime and offshore activities is loaded with requirement to build new sustainable and reliable technology for deep sea operation in order to fulfil alternative mitigation options for climate change, decline of coastline resources and enthophication. Expanding deep sea operation require development of technology related to dynamic position, mobile berthing facilities, collision aversion, impact of new environment, wave, wind on marine structure, supply vessel operation and fact that coastal water transportation attracts low probability and high consequence accidents. This makes reliability requirements for the design and operability for safety and environmental protection very necessary. This paper discusses process work in risk, hazard and reliability based design and safe and efficient operability deep water operation waters. This includes a system based approach that covers proactive risk as well as holistic multi criteria assessment of required variables to deduce mitigation options and decision support for preventive, protective and control measures of risk of hazard for deep water marine offshore operation.

Keywords: Deepwater; Environment; Marine Risk; Reliability; Safety;

Introduction

Offshore operation and marine transportation service provide substantial support to various human activities; its importance has long been recognized. The clear cut advantage of inland transportation over other modes of transportation, short sea service and evolving deep sea activities are being driven by recent environmental problems and dialogues over alternative renewable ways of doing things. The criticality of offshore and marine transportation operations within the coastline and the prohibitive nature of the occurrence of accidents due to high consequence and losses have equally made it imperative and necessary to design operate and maintain sustainable, efficient and reliable deepwater offshore operation and marine transportation systems. Marine accidents fall under the scenarios of collision, fire and explosion, flooding, and grounding. This paper discusses a model of reliability for the assessment and analysis of marine accident scenarios leading to design for the prevention and protection of the environment. The paper will address risk process that can optimize design, existing practice, and facilitate decision support for policy accommodation for evolving offshore deepwater regime [44,45].

Risk reliability modelling requirement: In order to build reliable deep water offshore system and supporting transportation system, it is important to understand the need analysis through examination of the components of system functionality and capability. This functionality capability of the platform, environmental loading and other support system environmental risk as well as ageing factors related to design, operation, construction, maintenance, economic, social and disposal requirement for sustainable marine system need to be critically analysed. Risk identification work should be followed by risk analysis that include risk ranking, limit acceptability and generation of best options towards development of safety and environmental risk mitigation and goal based objective for evaluation of the development of sustainable cost effective inland water transportation that fall under new generation green technology [46,47]. Weighing of deductive balancing work requirement for reliable and safety through iterative components of all elements involved should include social, economic, health, ecological and technological considerations. Other concerns are related to other uses of water resources and through best practice of sediment disposal, mitigation for environmental impact, continuous management, monitoring, and compensation for uncertainty as well as preparation for future regulation beyond compliance policy or principles.

Risk assessment has been used by the business community and government, and safety cases of risk assessment have been used by United Kingdom (UK) Health Safety and Environment (HSE). In the maritime industry, risk assessment has been used for vessel safety, marine structure, transportation of Liquefied Natural Gas (LNG) and offshore platforms. In Europe maritime risk assessment has been used for coastal port risk analyses and pilot fatigue. International Maritime Organization (IMO) and United State Coast Guard (USCG) rule making have issued guidelines and procedures for risk based decision making, analysis and management under formal safety assessment [48,49]. Risk analysis when used for rulemaking is called Formal Safety Assessment (FSA), while when it is used for compliance is addressed as Quantitative Risk Analysis (QRA). Contemporary time has seen risk assessment optimization using scenario based assessments, which considered the relative risks of different conditions and events. In the maritime industry, contemporary time risk assessment has been instrumental to make reliable decisions related to prediction of flood, structural reliability, intact stability, collision, grounding and fire safety. Probabilistic and stochastic risk assessment and concurrent use of virtual reality simulation that considers the broader impacts of events, conditions, scenarios on geographical, temporal impacts, risks of conditions is important to for continuous system monitoring. Additionally, sensitivity and contingency (what if) analyses can be selectively used as tools to deal with remnant reliability and uncertainty that answer hidden questions in dynamic and complex systems [50].

System Failure and Risk Based Design Requirement for Deep Water System: A basic principle for risk-based design has been formulated: the larger the losses from failure of a component, the smaller the upper bound of its hazard rate, the larger the required minimum reliability level from the component. A generalized version and analytical expression for this important principle have also been formulated for multiple failure modes. It is argued that the traditional approach based on a risk matrix is suitable only for single failure modes/ scenarios. In the case of multiple failure modes (scenarios), the individual risks should be aggregated and compared with the maximum tolerable risk. In this respect, a new method for risk-based design is proposed, based on limiting the probability of system failure below a maximal acceptable level at a minimum total cost (the sum of the cost for building the system and the risk of failure). The essence of the method can be summarized in three steps: developing a system topology with the maximum possible reliability, reducing the resultant system to a system with generic components, for each of which several alternatives exist including non-existence of the component, and a final step involving selecting a set of alternatives limiting the probability of system failure at a minimum total cost. Determining the set of alternatives for the components can be facilitated through the following elements.

The goal of risk based design for marine system and its goal is to enhance safety. Advantage of such system in system design includes:

- Establishment of systematic method, tools to assess operational, extreme, accidental and catastrophic scenarios and integrating human elements into the design environment
- Development of safety based technology for reliable operation and deign
- Establishment of regulatory framework to facilitate first principle approach to facilitate first principle approaches to safety
- Development of model that can demonstrate validation and practicability

Today, design shift towards knowledge intensive product, risk based design is believed to be key elements for enhancement of industrial competitiveness. The use of risk based design, operation and regulation open door to innovation and radical novel and inventive, and cost effective design solution. Risk based approach for ROV follow well established quantitative risk analysis used in offshore industries. The key to successful use of risk based design require advance tool to determine the risks involved and to quantify the effects of risk preventing/reducing measures as well as to develop (evaluation criteria to judge their cost effectiveness. Components of integrated risk include:

Front End: Model potential causes, locations, sizes, and likelihoods of acid releases from System. Analysis of system capabilities: identify those releases that are mitigatable.

Successful mitigation: release less than 1,500 gallons

Consideration of diagnosis and response times

Back End: Model potential failure modes of each system design, and estimate failure likelihoods

Analysis of system reliabilities reliability block diagram analysis systematic identification of failure

Modes: human errors, equipment failures, support system failures

Analysis of consequences of unmitigatable or unmitigated releases:

Release size used as surrogate consequence measure

Risk can be calculated from:

$$R = \sum \left(\mathrm{I_m} \, \mathrm{X} A_{mn} \mathrm{X} C_m \right) + \sum \left(J_i \mathrm{X} D_i \right) \quad (1)$$

Where: R = Risk metric, Im = Annual probability of mitigatable leak at location/size m, Ji = Annual probability of unmitigatable leak at location/size I, Amn = Probability of AIES failure via moden given leak m, Cm/Di = Consequence severity of leak m.

ROV operating capabilities requirement that can be investigated is under risk based design are:

- Standardized intervention ports for all subsea BOP stacks to ensure compatibility with any available ROV

- Visible mechanical indicator or redundant telemetry channel for BOP rams to give positive indication of proper functioning (e.g., a position indicator).
- ROV testing requirements, including subsea function testing with external hydraulic supply.
- An ROV interface with dual valves below the lowest ram on the BOP stack to allow well-killing operations.

Electrical power requirement: General requirements refer to SOLAS requirements. Chapter-II-1 outlines requirements for Ship construction sub-division and stability, machinery and electrical installations. The five parts of these parts are: Part A-General, Part B-Sub-division and stability, Part C-Machinery installations, Part D-Electrical installations, Part E-Additional requirements for periodically unattended machinery spaces.

Benefits and Limitations of Using Risk and Reliability Models: Rampant system failure and problems related to reliability have brought the need to adopt a new philosophy based on top down risk and life cycle model to design, operate and maintain systems based on risk and reliability. Likewise, election of alternative ways to mitigate challenges of safety and environmental risk of system deserve holistic, reliability analysis approaches that provide the following benefits:

- Flexibility and redundancy for innovative, alternative improvised design and concept development
- Evaluation of risk reduction measure and transparency of decision making process
- Systematic tool to study complex problem
- Interaction between disciplines
- Risk and impact valuation of system
- Facilitate proactive approach for system, safety, current design practice and management
- Facilitate holistic touching on contributing factor in system work
- Systematic rule making, limit acceptability and policy making development
- Analysis of transportation system

The dynamic distributive condition, long incumbent period and complexity of marine system with limited oversight makes the process of identification and addressing human as well as organizational error including checks and balances, redundancy, and training more complicated. Other inherits drawbacks associated with risk and reliability model are [51,52]:

- Lack of historical data (frequency, probability, expert judgment)
- Linking system functionality with standards requirement during analysis (total safety level vs. individual risk level, calculation of current safety level)
- Risk indices and evaluation criteria (individual risk acceptance criteria and sustainability balance)
- Quantification of human error and uncertainty

The complexity associated with human and organization requires human reliability assessment and uncertainty analysis to be modeled independently.

Marine Pollution Risk Challenges: A group of experts on the scientific aspects of marine pollution comment on the condition of the marine environment in 1989, stated that most human product or waste ends their ways in the estuarine, seas and finally to the ocean. Chemical contamination and litter can be observed from the tropics to the poles and from beaches to abyssal depths. But the conditions in the marine environment vary widely. The open sea is still considerably clean in contrast to inland waters. However, time continue to see that the sea is being affected by man almost everywhere and encroachment on coastal areas continues worldwide, if unchecked. This trend will lead to global deterioration in the quality and productivity of the marine environment [51].

This shows the extent and various ways human activities and uses water resources affect the ecological and chemical status of waterways system. Occurrence of accident within the coastline is quite prohibitive due to unimaginable consequences and effects to coastal habitats. Recent environmental performance studies on transportation mode has revealed that transportation by water provides wide advantages in term of less, low Green House Gas (GHG) release, large capacity, congestion, development initiative etc. These advantages tells about high prospect for potential modal shift of transportation and future extensive use of inland water marine transportation where risk based system will be necessary to provide efficient, sustainable and reliability safe clean waterways as well as conservation of environment.

This equally shows that increase in human activities will have potential effects in coastal and marine environment, from population pressure, increasing demands for space, competition over resources, and poor economic performances that can reciprocally undermine the sustainable use of our oceans and coastal areas. Different forms of pollutants and activities that affect the quality of water, air and soil as well as coastal ecosystems are: Water: pollution release directly or washed downed through ground water: Air pollution, noise population, vibration, Soil: dredge disposal and contaminated sediments, Flood risk: biochemical reaction of pollution elements with water, Collision: operational, and Bio diversification: endangered and threatened species, habitat.

Main sources of marine pollution: Point form pollution, Nonpoint form pollution.

Point form pollution: toxic contaminants, marine debris and dumping

Nonpoint form pollution: sewage, alien species, and watershed Issues.

Main sources from ships are in form of: Operational, Accidental risk.

Operational: operational activities along the shipping routes discharging waters contaminated with chemicals (whether intentionally or unintentionally)

Accidental risk: Collision due to loss of propulsion or control.

Risk associated with environmental issue in the context of ship, design has impacts related to shipping trends, channel design criteria, ship and oil platform manoeuvrability and dynamic positioning and ship controllability.

Modeling the risk and reliability components of complex and dynamic system: The consequence of maritime accident comes with environmental problem. Marine system are dynamic system that have potential for high impact accidents which are predominately associated with equipment failure, external events, human error, economic, system complexity, environmental and reliability issues. This call for innovative methods, tools to assess operational issue, extreme accidental and catastrophic scenarios. Such method should be extensive use to integration assessment of human element, technology, policy, science and agencies to minimise damage to the environment. Risk based design entails the systematic risk analysis in the design process targeting risk prevention and reduction as a design objective. They should be integrated with design environment to facilitate and support sustainable approach to ship and waterways designs need (Figure 61).

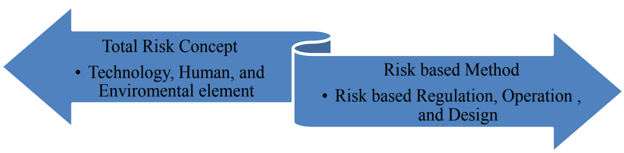


Figure 61: Risk modeling Components.

Integrated risk based system design requires the availability of tools to predict the safety performance and system components as well as integration and hybridization of safety and environmental factors, lifecycle phases and methods. It important to develop refines, verify, validate through effective methods and tools. Such integrative and total risk tools required logical process with holistic linkage between data, individual risk, societal, organizational, system description, conventional laws, principle for system design and operation need to be incorporated in the risk process. Verification and employment of system based approach in risk analysis should be followed with creation of database and identification of novel technologies required for implementation. Unwanted event which remain the central front of risk fight is an occurrence that has associated undesirable outcome which range from trivial to catastrophic. Depending on conditions and solution based technique in risk and reliability work, the model should be designed to protect investment, properties, citizens, natural resources the institution which has to function in sustainable manner within acceptable risk.

The risk reliability modeling process begins with definition of risk which stands for the measure of the frequency and severity of consequence of an unwanted event. Frequency at which a potential undesirable event occurs is expressed as events per unit time, often per year. Upon establishing understanding of whole system from baseline data that include elements of channel and vesseldimensioning as shown in Figure 62, the frequency can be determined from historical data. However, it is quite inherent that event that does not happen often attract severe consequence and lack data, such event is better analysed through probabilistic and stochastic model hybrid with first principle and whatever data is available [53]. Incidents are unwanted events that may or may not result to accidents if necessary measure is taken according to magnitude of event and required speed of response.While accidents are unwanted events that have either immediate or delayed consequences. Immediate consequences variables include injuries, loss of life, property damage and persons in peril. Point form consequences variables include further loss of life, environmental damage and financial costs.

$$\text{Risk } (R) = \text{Probability } (P) \text{ X Consequence } (C) \qquad (2)$$

The earlier stage of the risk and reliability process involves finding cause of risk, level of impact, destination and putting a barrier by all means in the pathway of source, cause and victim. Risk and reliability process targets the following:

Risk analysis and reduction process: This involves analytic work through selective deterministic and probabilistic method that assures reliability in the system. Reduction process will target initial risk reduction at design stage, risk reduction after design in operation and separate analysis for residual risk for uncertainty and human reliability.Risk in complex systems can have its roots in a number of factors ranging from performance, technology, human error as well as organizational cultures, all of which may support risk taking or fail to sufficiently encourage risk aversion.

Cause of risk and risk assessment: This involve system description, identifying the risk associated with the system, assessing them and organizing them according to degree of occurrence and impact in matrix form causes of risk can take many ways including the following:

Root cause: Inadequate operator knowledge, skills or abilities, or the lack of a safety management system in an organization.

Immediate cause: Failure to apply basic knowledge, skills, or abilities, or an operator impaired by drugs or alcohol.

Situation causal factor: Number of participants time/planning, volatility environmental factors, congestion, time of day risk associated with system can be based on.

Organization causal factor: Organization type, regulatory environment, organizational age management type/changes, system redundancy, system incident/accident history, individual, team training and safety management system.

To deal with difficulties of risk migration marine system (complex and dynamic by nature), reliability assessment models can be used to capture the system complex issues as well as patterns of risk migration. Historical analyses of system performance is important to establish performance benchmarks in the system and to identify patterns of triggering events which may require long periods of time to develop and detect. Like wise, assessments of the role of human/organizational error and their impact on levels of risk in the system are critical in distributed, large-scale systems. This however imposes associated physical oversight linked to uncertainty during system design. Effective risk assessments required three elements:

1) Framework

2) Model

3) Process

Risk framework: Risk framework provides system description, risk identification, criticality, ranking, impact, possible mitigation and high level objective to provide system with what will make it reliable. The framework development involves risk identification which requires developing a structure for understanding the manner in which accidents, their initiating events and their consequences occur. This includes assessment of representative system and all linkages that are associated to the system functionality and regulatory impact.

Model: The challenges of risk and reliability method for complex dynamic systems like ship motion at sea require reliable risk models. Risk mitigation measures can be tested and the tradeoff between different measures or combinations of measures can be evaluated. Changes in the levels of risk in the system can be assessed under different scenarios and incorporating "what if" analyses in different risk mitigation measures. Performance trend analysis, reassessment of machinery, equipment, and personnel can be helpful in assessing the utility of different risk reduction measures. Figure 62 and 63 shows the risk components, system functionality and regulatory requirement for reliability model that can be followed for each risk scenario.

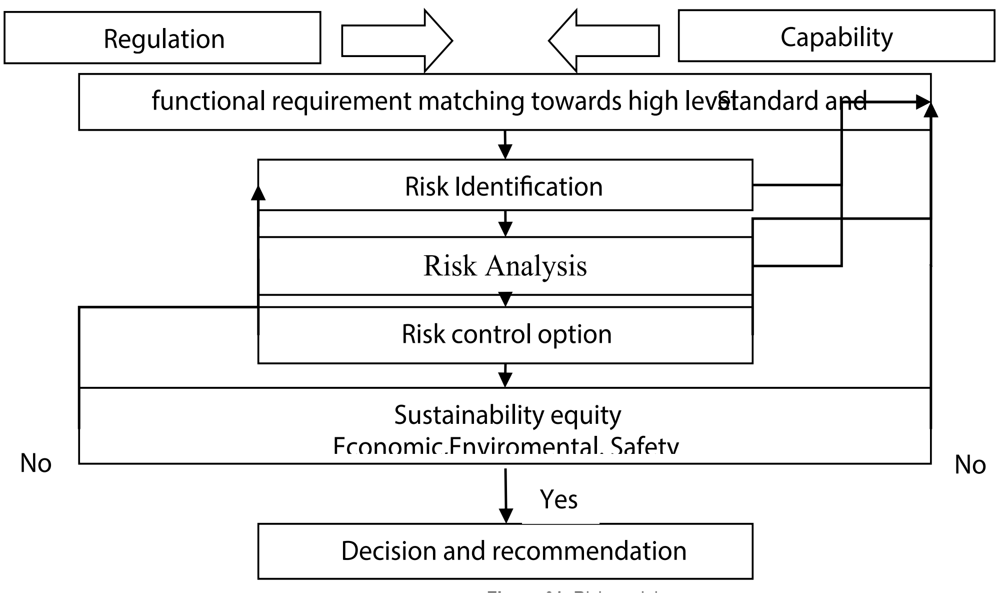


Figure 62: Risk model.

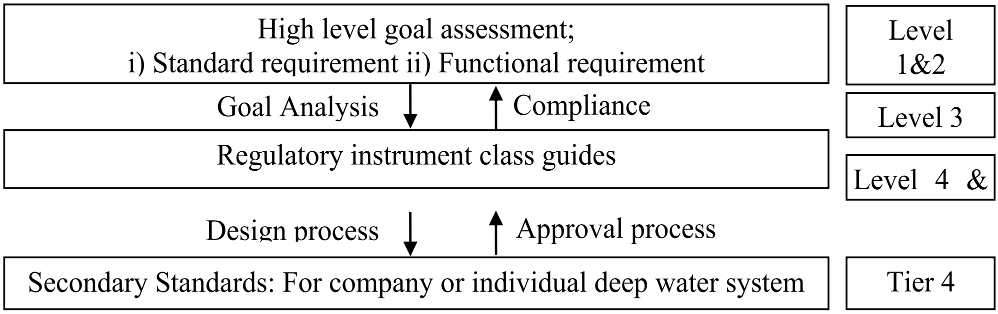


Figure 63: Goal based assessment.

Process: The process should be developed to provide effective and sound risk analysis where accuracy, balance information that meets high scientific standards of measurement can be used as input. This requires getting the science right and getting the right science by targeting interests of stakeholders including port, waterway community, public officials, regulators and scientists. Transparency, community participation, additional input to the risk process, checks the plausibility of assumptions could help ask the right questions of the science. Total integrated risk can be represented by:

$$Rt = fs\ (Rc, Rw, Re, Rs) \qquad (3)$$

Where: Re (environment) = fe (sensitivity, advert weather…), Rs (ship) = fs (structural and system reliability, ship layout and cargo arrangement…), Rc (crew) = fc (qualification, fatigue, etc)

Holistic and integrated risk based method combined various techniques in a process as depicted in Figure 64 and 65, this can be applied for each level of risk for system in question. Each level is complimented by applying causal analysis (system linkage), expert analysis (expert rating) and organizational analysis (Community participation).

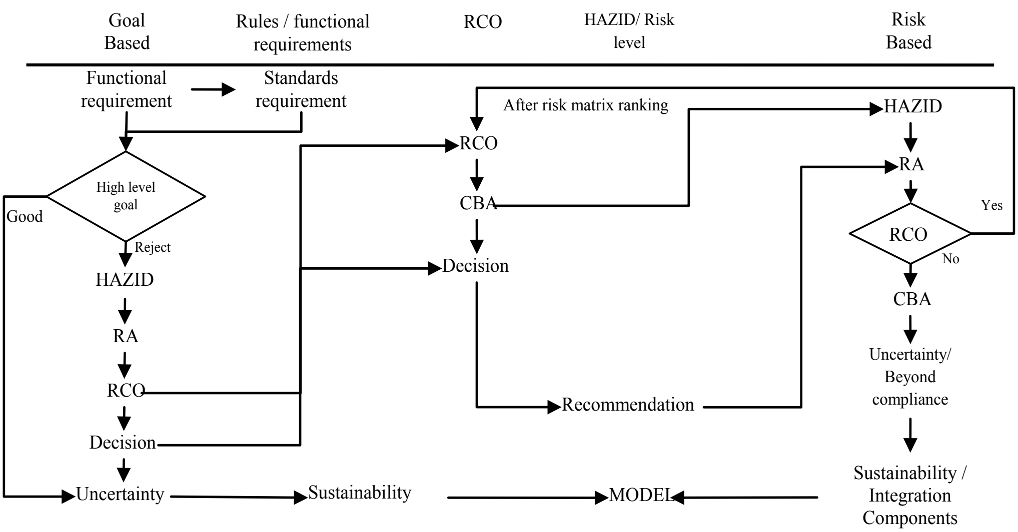


Figure 64: Holistic Risk analysis Process Map.

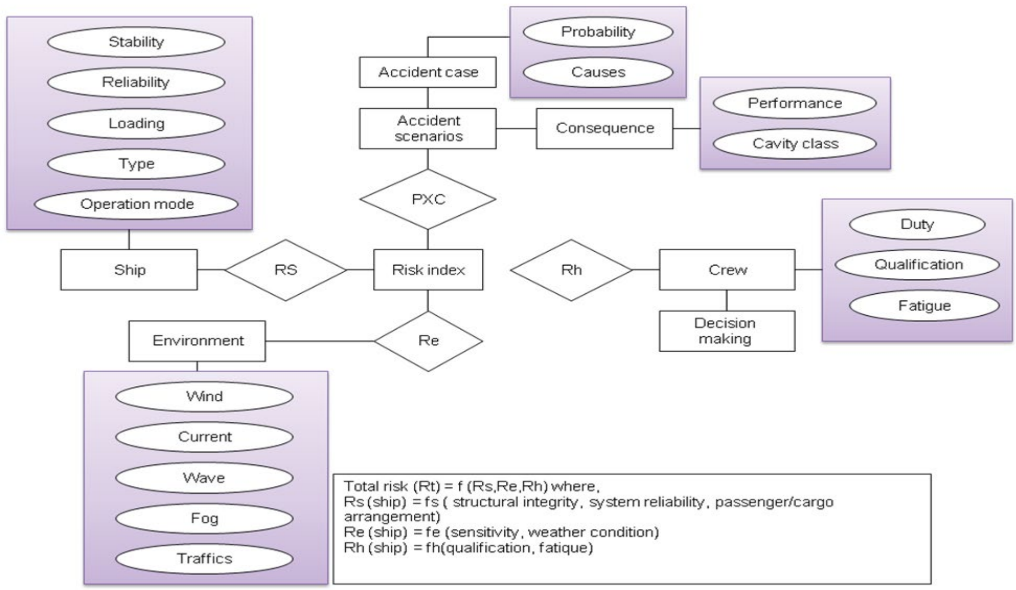


Figure 65: Holistic risk analysis process.

Table 27 shows models that have been used in the design system based on risks. IMO and Sirkar et al.,[12] methods lack assessment of the likelihood of the event. Other models lack employment of stochastic method whose result may cover uncertainties associated with dynamic and complex components of channel, ship failure and causal factors like navigational equipment, better training and traffic control. Therefore, combination of stochastic, statistical, reliability and probabilistic together with hybrid employment of goal based, formal safety assessment methods and fuzzy multi criteria network method that use historical data of waterways, vessel environmental and traffic data could yield efficient, sustainable and reliable design product for complex and dynamic systems. The general hypothesis behind assessing physical risk model of ship in waterways is that the probability of an accident on a particular transit depends on a set of risk variables which required to be analyzed for necessary conclusion of prospective reliable design [54].

Process	Suitable techniques
HAZID	HAZOP, What if analysis, FMEA, FMECA
Risk analysis	FTA, ETA
Risk evaluation	Influence diagram, decision analysis
Risk control option	Regulatory, economic, environmental and function elements matching and iteration
Cost benefit analysis	ICAF, Net Benefit
Human reliability	Simulation/ Probabilistic
Uncertainty	Simulation/probabilistic
Risk Monitoring	Simulation/ probabilistic

Table 27: Risk Model.

Risk and reliability modeling involves hazard identification, risk screening, broadly focused, narrowly focused and detailed Analysis, Table 27 shows iterative method that can be incorporated for various needs and stages of the process.

Accident analysis: Accident and incident need to be prevented as the consequence of is a result of compromise to safety leading to unforgettable losses and environmental catastrophic. Past engineering work has involved dealing with accident issues in reactive manner. System failure and unbearable environmental problems call for new proactive ways that account for equity requirement for human, technology and environment interaction in the system. The accidental categories and potential failure in waterways is shown in Figure 66.

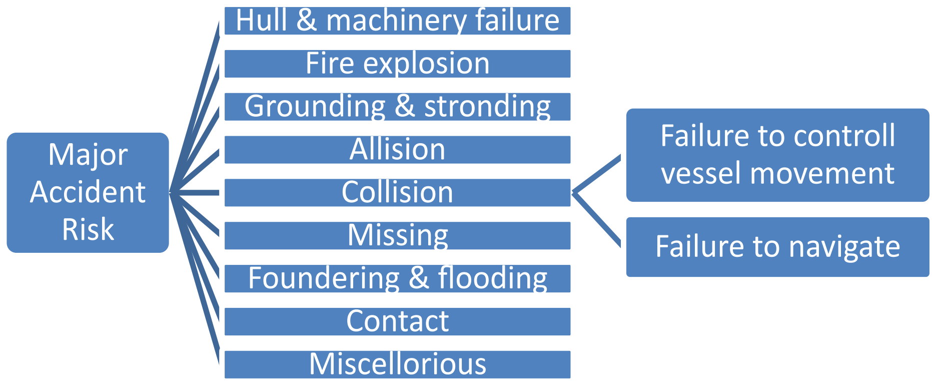


Figure 66: Accident scenario.

The methodologies that may be used to identify safety critical systems, subsystem and elements include:

Major Accident Hazard: definition, examples, compliance with regulations such as SEVESOII (COMAH) and PFEER.

Qualitative method for determination of the safety risk including: Brain storming session methodology and example-safety criticality criteria. Required supporting documents and evidences Action tracking

Quantitative method for frequency and consequence analysis: Quantitative Risk Analysis (QRA) is widely use quantitative method for offshore industry, while Formal Safety Assessment (FSA) is use in marine industry. QRA should be simplified for to be used for determination for safety criticality criteria, safety criticality test for failure on demand and time of test/repair, HSE toolkit application, combined Event tree, Fault tree Analysis. Standards safety critical elements identification could be analyzed through development of risk matrix,regulation scope and boundary compliance, performance standard and assessment, system capability, functionality, reliability, survivability assurance and verification analysis.The dynamic risk analysis process starts with system description, functionality, regulatory determination and this is followed with analysis of [46]:

- Fact gathering for understanding of contribution factor.
- Fact analysis for check of consistency of accident history.
- Conclusion on causation and contributing factor.

Counter measures and recommendations for prevention of accident and studies of the system or project. Major areas of concern of HSE analysis are:

- Examination of relevant case of risk, hazard, Process Safety and reliability leading to HAZID.
- Identification of Safety Critical Elements.
- Examination and comparison of performance standards.
- Examination of release and consequence model (Fire, Explosion and Toxic Release Consequence Modelling & Design).
- Training on fundamental of the Risk Assessment & Case Study and Implementation of HSE Management System.
- Conduct of HAZOP Methodology and Simultaneous Operation.

- Risk Based Design acceptability criteria and & Integrity Assurance.
- Applications of Dynamic Simulation in Process Safety Design.
- Risk management, life cycle, traceable and auditable reference different phases of the project.

Risk analysis is conducted using brain storming worksheets, action tracking and follow-up.HAZID, HAZOP involve Process safety Engineers, plant managers, safety supervisors, process engineers, safety Engineers and discipline engineers.

Elements of QRA include: Failure Case definition, Consequence assessment, Frequency analysis, Risk calculation, ALARP demonstration, Identification of Safety Critical Systems, Traceability and audibility of Safety Critical Elements.

HAZARD operability (HAZOP): Hazard operability (HAZOP) is done to ensure that the systems are designed for safe operation with respect to personnel, environment and asset. In HAZOP all potential hazard and error, including operational issues related to the design is identified. A HAZOP analysis is detail HAZID, it mostly divided into section or nodes involve systemic thinking and assessment a systematic manner the hazards associated to the operation. The quality of the HAZOP depends on the participants. Good quality of HAZOP participants are [55]. Politeness and unterupting to the point discussion avoid endless discussion, be active and positive, be responsible and Allow HAZOP leader to lead.

It involve How to apply the API 14C for those process hazard with potential of the Major Accident. Dynamic simulation for consequence assessment of the process deviation, failure on demand and spurious function of the safety system, alarm function and operator intervention is very important for HAZOP study. Identification of HAZOP is followed with application of combined. Event tree and Fault tree analysis for determination of safety critical elements, training requirement for the operators and integrity and review of maintenance manuals. HAZOP involved use of the following:

Guide word i.e. No pitch, No blade

Description: i.e. No rotational energy transformed, object in water break the blade

Causes: i.e. operation control mechanism

Safety measurement to address implementation of propeller protection such grating, jet

The following are some of the guideword that can be used for Propulsion failure HAZOP includes: no pitch, no blade, no control bar, no crank.

HAZOP process is as followed:

Guide word/brain storming-> Deviation-> Consequence-> Safeguard->Recommended action

Also important HAZOP is implementation of IEC61511 to assess the hazards associated to failure on demand and spurious trips. In HAZOP record the worksheets efficiently to cover all phases also play important role. Advance HAZOP can also e implemented through Simulation operations to identify, quantify, and evaluate the risks. SIMOP Methodology includes: Consequence Assessment, Frequency Analysis, Risk Calculation, Risk Analysis, and Safety Criticality Elements. HAZOP is not intended to solve everything in a meeting. Identified hazard is solved in the closing process of the finding from the study. Table 28 shows typical HAZOP report. Safety barrier management involves optimisation between the preventive and mitigation measuresfundamental.

Safety barrier management helps in determination of the Safety Critical Elements (SCE), performance standards for the design of safety Critical Elements and in integrity assurance. Safety Level Integrity (SIL) involves assessment and verification according to IEC61508 and IEC61511Qualitative SIL assessment uses the risk graphs and calibration tables during the brain storming sessions where the required SIL is assigned to the safety systems. Integrity and insurance Involve iteration of assessment of identification the credible scenarios, consequence assessment, frequency analysis, risk calculation, risk evaluation and ranking. Dynamic simulation help to identify the process hazards, measure the extent and duration of the consequences and the effect and efficiency of the safety barriers. With dynamic simulation could be optimised with greater accuracy. This saves a significant effort, time and cost for the project. It involves application of: HAZOP & SIL assessment, Alarm Management, Fire & Explosion and Case study.

Compression area	Fire	Hot work	3
Manfold area	Toxicity	Radioactive products	4
HP gas area	PPE		2
Separation area	Management of work permit (A)	If PTW is not followed correctly , the accident may happen	3
Compressor area	Fire & Explosion		3
Process area	Handling	Handling of proximity of process under pressure	4
Utility area	Fire fighting system	No availability of Fire Fighting system	2
Separation	Fire & Explosion	Escape routes are obstructed	3
	PPE	Contractor not using PPE	2
	PPE		3
Tank area	Fire	No Fire & Gas detection	2
Compression area	Explosion	Escape routes are obstructed	3
Compression area	Fire	Hot work	3
Manfold area	Toxicity	Radioactive products	4

Table 28: Typical HAZOP report.

Subsystem analysis-Fire and explosion: Consequence modelling of Fire, Explosion and Toxic release, understanding of the fundamental and the science, governing scenarios, consequence analysis criteria. Gas dispersion & hazardous area classification, Fire zones (passive fire protection zones, the active fire protection zones, Blast Zones, blast protection zones restricted areas) Thermal & blast effect on equipment, people and environment is important to be incorporated in the risk process. Figure 67 shows a typical fire and explosion risk model.

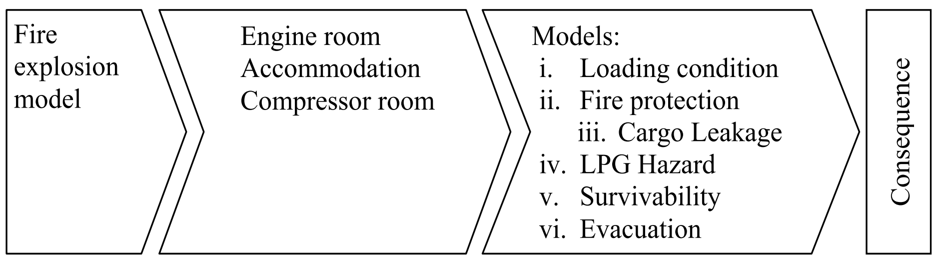


Figure 67: Typical fire and explosion risk model.

Collision scenario: Collision is the structural impact between two ships or one ship and a floating or still objects that result could to damage. Collision is considered infrequent accident occurrence whose consequence ineconomical, environmental and social terms can be significant. Prevention of collision damages is likely to be more cost-effective than mitigation of its consequences. Probabilistic predictions can be enhanced by analyzing operator effects, drifting and loss of power or propulsion that take into account ship and waterway systems, people and environment into consideration. Other causative factor like the probability of disabled ship as function of ship type, the probability of a disabled ship drifting towards objects also need to be accounted for. The collision model scenario also involves data that characterize of hull areas and environmental information. Figure 68 show a typical collision consequence situation [52,56,57].

Figure 68: Cause of collision (Langat River).

Outcome of analysis is followed by suitable Risk Control Options (RCO), where iteration of factual functionality and regulatory elements is checked with cost. The benefit realised from safety, environmental protection and effect of the probability of high level of uncertainty associated with human and organizational contributing factor to risk of collision are also important. The risk process functions to determine and deduce the idea for modest, efficient sustainable and reliable system requirement and arrangement [20,56]. Collision carried the highest statistic in respect to ship accident and associated causality. The consequences of accident are:

- The loss of human life, impacts on the economy, safety and health, or the environment
- The environmental impact, especially in the case where large tankers are involved. However, even minor spills from any kind of merchant ship can form a threat to the environment
- Financial consequences to local communities close to the accident, the financial consequence to ship-owners, due to ship loss or penalties
- Damage to coastal or off shore infrastructure, for example collision with bridges

Accident events are unplanned, always possible, but effectively manageable and frequently preceded by related events that can be detected and corrected by having underlying root causes ranging from human errors, equipment failures, or external events. The result of frequency and consequence analysis is checked with riskacceptability index for industry of concerned. Table shown in Tables 29 and 30 shows risk acceptability criteria for maritime industry. The analyzed influence diagram deduced from the comparison can be followed with cost control option using cost of averting fatality index or Imply Cost of Averting Fatality (ICAF) and As Low as Reasonable Possible (ALARP) principle [49].

Frequency Class	Quantification
Very unlikely	less than once per 10000 years (P<1/10000)
Remote	once per 100 -1000 years (1/1000= P< 1/100)
Occasional	once per 10 - 100 years (1/100 = P< 1/10)
Probable	once per 1-10 years (1/10=P<1)
Frequent	more than once per year (P =1)

Table 29: Frequency risk acceptability criteria for maritime industry.

Quantification	Serenity	Occurrence	Detection	RPN
current failure that can result to death failure, performance of mission	Catastrophic(10)	1	2	10
failure leading to degradation beyond accountable limit and causing hazard	Critical (7)	3	4	7
controllable failure leading to degradation beyond acceptable limit	Major(5)	4	6	5
Nuisance failure that do not degrade system overall performance beyond acceptable limit	Minor(1)	7	8	2

Table 30: Consequence risk acceptability criteria for maritime industry.

Failure Modes Effect Analysis (FMEA): A Failure Modes Effect Analysis (FMEA) is a powerful bottom up tool for total risk analysis. FMEA is probably the most commonly used for qualitative analysis and is also the least complex. FMEA has been employed in the following areas: The aerospace industry during the Apollo missions in the 1960s.The US Navy in 1974 developed a tool which discussed the proper use of the technique. Today, FMEA is universally used by many different industries. There are three main types of FMEA in use today:

System FMEA: concept stage design system and sub-system analysis.

Design FMEA: product design analysis before release to manufacturers.

Process FMEA: manufacturing assembly process analysis.FMEA process is shown in Figure 69:

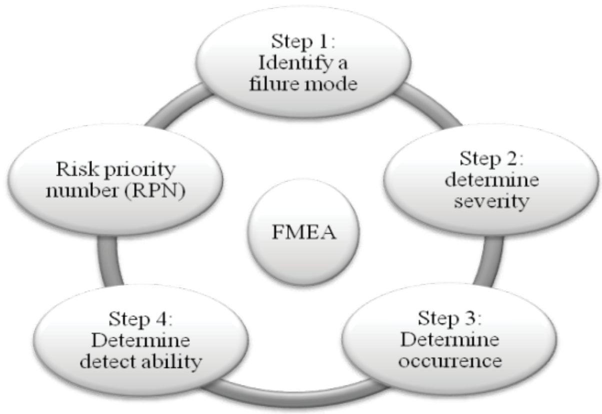


Figure 69: FMEA process.

It is strongly recommended that Serenity, Occurrence and Detection (SOD) for weak control should be noted. SOD numbers is multiplied and the value is stored in RPN (risk priority number) column. This is the key number that will be used to identify where the team should focus first. If, for example, we had a severity of 10 (very severe), occurrence of 10 (happens all the time), and detection of 10 (cannot detect it) RPN is 1000. This indicates a serious situation that requires immediate attention. The consequence could further be broken down into effect for ship, human safety, oil spill, damage, ecology, emission andother environmetal impacts.Number 1-10 are assigned according to level of serenity. Risk priority number (RPN) for total serenity is determining as follows Table 31 show typical risk matrix arrangement:

$$RPN = S \times O \times D \quad (4)$$

ALARP Principal, Risk Acceptability Criteria And Risk Control Option

Risk acceptability criteria establishment is dynamic because of differences in environment, diversity in industries and choice of regulations requirement to limit the risk. Risk is never acceptable, but the activity implying the risk may be acceptable due to benefits of safety reduced, fatality, injury, individual risk, societal risk, environment and economy. The rationality may be debated, societal risk criteria are used by increasing number of regulators. Figure 70 shows ALARP diagram by IMO [45].

Figure 70 shows prescribed illustrative influence diagram by IMO. Based on the region where the graph falls, step for risk control option and sustainability balancing, cost benefit effectiveness towards recommendation for efficient, reliable, sustainable decisioncan is taken. The frequency (F) of accidents involving consequence (N) or more fatalities may be established in similar ways as individual or societal risk criteria. For risks in the unacceptable/Intolerable risk region, the risks should be reduced at any cost. Risk matrix constructed from system and sub system level analysis can be deduced according to acceptability index and defined according to Table 31 and Figure 11 to deduced measure of As Low as Reasonably Practicable (ALARP). Within ALARP range, Cost Effectiveness Assessment (CEA) or Cost Benefit Analysis (CBA) shown in Figure 70 may be used to select reasonably practicable risk reduction measures.

			Consequence Criteria				
			1 –Insignificant	**2 – Minor**	**3 – Moderate**	**4 – Major**	**5– Catastrophic**
	A	Consequence certain to occur	Medium (M)				
	B	Consequence likely to occur	Medium (M)	Medium (M)			
	C	Consequent possibly likely to occur some time	Low (L)	Medium (M)			
	D	consequence unlikely to occur but could happen	Low (L)	Low (L)	Medium (M)	Medium (M)	
Likelihood	**E**	consequence may occur only in exceptional circumstances	Low (L)	Low (L)	Medium (M)	Medium (M)	

Table 31: Risk Matrix.

ALARP = As Low As Reasonably Practicable: Risk level boundaries (Negligible/ALARP/ Intolerable)

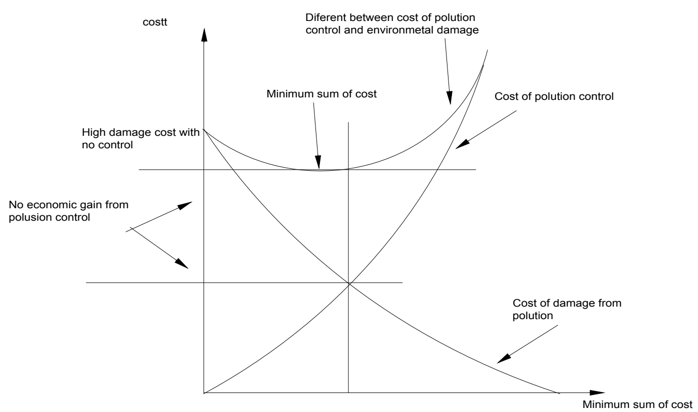


Figure 70: Risk cost benefit analysis.

Risk analysis considerations: In addition to a sound process, robust risk framework and eventual deductive risk model, there are other considerations that should be factored into the design of an effective risk model. These items include the use of available data, the need to address human factors, areas of interest, stake holder interest and approaches to treating uncertainty in risk analysis. Data required for risk work should involve information on traffic patterns, the environment (weather, sea conditions and visibility), historical, current operational performance data, and human performance data. The models intentions are highly dependent on appropriately selected databases that accurately represent the local situation and the effectiveness of the models However, there is always issue of missing data or data limitations especially for complex system and their allow frequency, high consequence nature. Therefore creative procedures are required to develop compensation for data relationships. The model could use probabilistic, stochastic, simulation and expert judgments couple existing deterministic and historical method for a reliable system analysis of desired design [57].

When insufficient local data is available, world wide data from other areas may be referred to (e.g., Europe, south and North America), make assumptions about the similarity of operations in the concerned area or elsewhere. This is to ensure how behaviour in one aspect of operational (e.g., company management quality) parameter (e.g., loss of crew time) correlates with another area (e.g., operations safety). The data from other areas can be used as long as major parameter and environmental factors are compared and well matched. Care is required with the use of worldwide data as much of those data are influenced by locations or local environmental conditions Electronic access to worldwide casualty data such as the Paris MOU, U.K. and Marine Accident Investigation Board (MAIB) and IMO Port State detention databases makes possible access to worldwide casualty statistics. Diligence should also be observed about the large number of small scale, localized incidents that occur that are not tracked by marine safety authorities, e.g small craft (not always registered or being able to be detected by VTS, AIS) accidents in waterways. American Bureau of Shipping (ABS) has begun an effort to identify precursors or leading indicators of safety in marine transportation.

Human factor modeling should be considered for distributive, large scale systems with limited physical oversight. Assessing the role of human and organizational performance on levels of risk in the system is important, such error is often cited as a primary contributor to accident, which end up leaving system with many more unknown. Expert judgments and visual reality simulation can be used to fill such uncertainty gaps and others like weather data. Even when attempts are made to minimize errors from expert judgments, the data are inherently subject to distortion and bias. With an extensive list of required data, there are limits that available data can place on the accuracy, completeness and uncertainty in the risk assessment results. Expert judgments give prediction about the likelihood that failures that would occur in specific situations can be used to quantify human reliability input in risk process.

Uncertainty is always part of system behaviour. Two common uncertainties are: aleatory uncertainty (the randomness of the system itself) and epistemic uncertainty (the lack of knowledge about the system). Aleatory uncertainty is represented by probability models while epistemic uncertainty is represented by lack of knowledge concerning the parameters of the model. Aleatory uncertainty is critical, it can be addressed through probabilistic risk analysis while epistemic uncertainty is critical to allow meaningful decision making. Simulation offers one best option to cover extreme case uncertainty beside probability. Evaluationand comparison of baseline scenario to a set of scenarios of interest (tugescort) and operational circumstance including timelines and roles. Response Scenarios can also be analyzed for things that cannot be imagined or model to be accounted for in the simulator (especially real time). A flexible critical path and slack analysis can be performed as input to the system simulation and uncertainty analysis. Human reliability is best modeled separately for a good result [48].

Risk and reliability can be achieved by employing probability stochastic and expert rating in the risk process. A safety culture questionnaire which assesses organizational and vessel safety culture and climate can be administered to provide quantitative and qualitative input to the safety culture and environmental perception analysis for sustainable system design.

Conclusion

Following need for maritime activities to operate in much harsh condition, institutions are adopting system based approach that account for total risk associated with system lifecycle to protect the environment and prevent accident. Those that cannot be prevented and protected need or must be controlled under risk and reliability based design/operability platform. Employment of risk method to address each contributing factor to accident is very important. Qualitative risk in system description and hazard identification can best be tackled through HAZOP. The outcome of HAZOP can be processed in quantitative analysis which may include probabilistic and stochastic dynamic simulation process for system level analysis, while fault tree and event tree quantitative analysis can be utilized to determine risk index of the subsystem factors. Interpretation of risk index into ALARP influence diagram can provide decision support information necessary for cost control option towards sustainable, reliable, efficient technology choice for system design and operation. The cumulative results from qualitative analysis can be made more reliable through iterative quantitative, scientific stochastic and reliability analysis. Risk methods provide valuable and effective decision support tool for application of automated system engineering analysis that facilitate inclusion of reliability, environmental protection and safety as part of the iterative design processes for new and innovative marine system designs, operability and deployment of deep sea operability system. Intelligently adoption of HAZOP and other risk processes eventually can results to safer, efficient, more reliable and sustainable system.

5. Environmental Risk Compliance for Nature Gas Ship Design and Operation

Abstract

The quests for an efficient fuel friendly to the environment have been recognized in maritime industry for a long time through improvements of gasoline and diesel by chemical reformulation. Inconvenience posed by these reformulation chemicals is performance problems; cold start ability, smooth operation and avoidance of vapor lock. Climate change problem has further aggravated need to use fuel that could contribute to decrease in green house gases and ozone-forming pollutants. Alternative fuels to petroleum have been identified to include, Compressed Natural Gas (CNG), liquefied petroleum gas (LPG); methanol from natural gas LNG. Selection of this towards centralized reduction of Green House Gases (GHGs) will depend on ease of use, performance and cost. LNG cargo is conditioned for long distance transfer while CNG and LPG cargo are conditioned for end user consumption and short distance transfer. It is therefore, clear that promoting the use of CNG will catalyze boosting of economy of coastal ship building and transportation, including environmental friendly utility fuel, and new generation of intermodal transportation and supply chain. Since the danger behind use of this gas could not be either underestimated by virtue regarding coastal operation proximity and consequence. The paper will discuss risk and potential regulation that will formulate beyond compliance, decision towards use of top-down risk based design and operations that will reinforce new integrative, efficient, environmental friendly, reliable multimodal and intermodal links advanced concepts for LPG ship operating in coastal and restricted waters.

Keywords: CNG; HAZOP; LNG; LPG; NG; Persekitaran; Penilaian Risiko; Rekaan Berdasarkan Risiko Dan Matlamat; Terusan; Tenaga;

Introduction

Fuel technology has been dominated with ways to improve gasoline and diesel by chemical reformulation that can lead increase efficiency and additional inconvenience leading to ozone depletion, green house and acid rain forming pollutants. Likewise, side effects problems posed to transportation vehicles have been dominated by condition, other performance issues. Time has shown that the global trend in de-Carbonization of the energy system follow the following path: Coal -> Oil-> Natural Gas -> Hydrogen

The drive towards environmentally friendlier fuels points next to Natural Gas (NG) and the infrastructures to support that trend are being pre-positioned by corporate mechanisms as well as governmental bodies worldwide. NG is cheap and its reserve is plentiful. Natural Gas as fuel is becoming more and more established in urban transport and Power Generation sectors. Its use will also take aggressive approach for all inland vessel including ferries in the eyes of potential environmental compliance new regulations. Internationally its operational record and GHG gas score is rated as GOOD. However, CNG, LPG and ethanol has been proven to be environmental friendly and has fuel economy of 50 percent. This shows that, CNG and LPG have potential for large market for use in niche markets in both developed and developing countries. Other gains from CNG and LPG depend on the amount of associated methane emissions from gas recovery, transmission, distribution, and use. On a full-cycle basis, use of LPG can result in 20-25% reduction in GHG emissions as compared to petrol, while emission benefits from CNG are smaller about 15% [58].

Furthermore, it is clear that promoting the use of CNG and LPG will be a catalyst to boost economy of coastal ship building, environmental friendly intermodal transportation for supply chain. Efficient and reliable operation can be made afforded by LPG, transportation, supply vessel, tugs to support this potential development. On the regulatory regime, IMO focus more on operational issues relating to carriage of gas with no specification for CNG and LPG, while the ICG code and class society guidelines elaborate on the design as well as operational consideration. Local administration imposes additional regulation as required for their respective implementation.

Time has revealed that there will be large demands for these gases. This paper focus on integrative use of IMO prescriptive goal and risk based standards with holistic consideration of factors require for safe design and operation of LPG ships in inland water. Including hybrid use of elements of Formal Safety Assessment (FSA) and Goal Based Standards (GBS) to prevent, minimize control and guarantee the life span of LPG ships and protection of environment. The paper will discussed top down environmental risk generic risk model and operations of LPG ship. It will describe the characteristics of LPG, regulatory issues and environmental issues driving today's beyond compliance and selection of new technology policy. Since it is the consequence of accident and incident that leads to environment disaster, the paper will discussed issues that allow prevention and control of accident. Since issues relating to global warming, GHG releases is strictly linked to ship energy source, the paper will also discuss impact areas and potential new technology driving beyond compliance policy adoption for LPG design and operation.

Natural gas and its products: Natural gas in its liquid state (LNG) or liquid natural gas that comprise of liquid hydrocarbons that are recovered from natural gases in gas processing plants, and in some cases, from field processing facilities. These hydrocarbons involve propane, pentanes, ethane, butane and some other heavy elements. LNG accounts for about 4% of natural gas consumption worldwide, and is produced in dozens of large-scale liquefaction plants. Natural gas contains less carbon than any other fossil fuel and, therefore produces less carbon Dioxide (CO_2) when compared to any conventional vehicles. Its usage also results in significantly less carbon monoxide (CO), as well as less combustive organic compounds than their gasoline counterparts. It is produced by cooling natural gas to a temperature of minus 260 degrees F (minus 160 Celsius). At this temperature, natural gas becomes liquid and its volume reduces 615 times. LNG has high energy density, which makes it useful for energy storage in double walled, vacuum insulated tanks as well as transoceanic transportation.

The production process of LNG starts with Natural Gas, being transported to the LNG Plant site as feedstock, after filtration and metering in the feedstock reception facility, the feedstock gas enters the LNG plant and is distributed among the identical liquefaction systems. Each LNG process plant consists of reception, acid gas removal, dehydration removal, mercury removal, gas chilling and liquefaction, refrigeration, fractionation, nitrogen rejection and sulfur recovery units. LPG and CNG are made by compressing purified natural gas, then stored and distributed in hard containers. Mostly, LPG station is created by connecting a fuel compressor to the nearest natural gas pipeline distribution system. The process through which Liquefied Natural Gas is produced consists of tree main steps, namely:

Transportation of gas: The best place to install the plant is near the gas source. The gas is basically transported through pipelines or by truck and barge.

Pretreatment of gas: The liquefaction process requires that all components that solidify at liquefaction temperatures must be removed prior to liquefaction. This step refers of treatment the gas requires to make it liquefiable including compression, filtering of solids, removal of liquids and gases that would solidify under liquefaction, and purification which is removal of non-methane gases.

Liquefaction of gas: Today, alternative fuels to petroleum have been identified to include Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), methanol from natural gas, coal or biomass; ethanol from biomass, electricity and hydrogen. However NG quality may be expressed with the Wobbe Index. Methane Number MN80 (Volume percent hydrogen atoms/carbon atoms) or Methane->=88%

Since 1960s, CNG and LPG are recognized as vehicle fuel alternative to oil-based gasoline and diesel fuel that reduces pollution of the air. It is a natural gas compressed to a volume and density that is practical as a portable fuel supply. Compressed Natural Gas (CNG) and Liquefies Petroleum Gas (LPG) are use as consumer fuel for vehicles, cooking food and heat homes. There exist a vast number of natural gas liquefaction plants designs, but, all are based on the combination of heat exchanger and refrigeration. The gas being liquefied, however, takes the same liquefaction path. The dry, clean gas enters a heat exchanger and exits as LNG. The capital invested in a plant and the operating cost of any liquefaction plant is based on the refrigeration techniques.

Natural gas is transported through pipelines to refuelling stations then compressed at a pressure of 3,000 psi with the help of specially installed compressors that enables it to be loaded as gas cylinders for vehicles. The process consists of drawing the natural gas from underground pipelines by the compressor. The composition of pipeline natural gas varies considerably depending on the time of year, pipeline demand, and pipeline system. It may contain impurities, like oil, particulates, hydrogen sulphide, oxygen or water. Hence, the modern day, quality LPG plant system consists of facilities to address these problems. Using LNG as the feedstock to make CNG and LPG eliminates or mitigates each of the above stated concerns as contains no water or any such impurity. This eliminates the concerns for corrosion, plugging of fuel lines, and the formation of hydrates. Significant design innovation will involve developmentof liquefied gas technology that promises lower costs and shorter scheduling time than Liquefied Natural Gas technology or a pipeline transport as well as provision of unique solution to the development of distressed or stranded gas reserves and alternative to associated gas re-injection. Liquefied Petroleum Gas (LPG) can also be produced either as a by-product when refining crude oil or direct from the gas wells. The two most common LPG gases are known as Commercial Propane and Commercial Butane as defined in BS 4250 [59].

Up to 15 kg and generally used for leisure applications and mobile heaters. Commercial Propane is predominately stored in red cylinders and bulk storage vessels and especially used for heating, cooking and numerous commercial and industrial applications. LPG has one key characteristic that distinguishes it from Natural Gas. Under modest pressure LPG gas vapor becomes a liquid. This makes it easy to be stored and transported in specially constructed vessels and cylinders. The combustion of LPG produces Carbon Dioxide (CO_2) and water vapor therefore sufficient air must be available for appliances to burn efficiently. Inadequate appliance and ventilation can result in the production of toxic Carbon Monoxide (CO). All things being equal, it produces much less hydrocarbon compare to diesel. Hazards associated with LPG ships are linked to the gas characteristics that attract beyond compliances operability and design policy. Selection of this towards centralized reduction of GHGs will depend on ease of use, performance and cost.

Natural gas properties: Everyone dealing with the storage and handling of LPG should be familiar with the key characteristics and potential hazards. Matter either in their solid, a liquid or a gaseous form is made from atoms which combine with other atoms to form molecules. Air is a gas, in any gas, large numbers of molecules are weakly attracted to each other and are free to move about in space. A gas does not have a fixed shape or size. Each gas that the air is composed of consists of various different properties that add to the overall characteristics of a particular gas [60]. Gases have certain physical and chemical properties that help to differentiate a particular gas in the atmosphere. Depending on different properties the gases are used widely in several applications. Below are some of the gases properties Natural gas may consist of:

Methane CH_4 -> .80%

Ethane C_2H_6 ->.20%

Propane C_3H_8 ->20%

Butane C_4H_{10} ->20%

Carbon Dioxide CO_2->.8%

Oxygen O_2 ->0.2%

Nitrogen N_2 ->5%

Hydrogen sulphide H_2S ->5%

Rare gases-> A, He, Ne, Xe trace

Hazards associated with LPG ships are linked to the gas characteristics and beyond compliances operability and design. CNG are a non toxic gas liquid at -259°F/-162°C which ignites at 1350°F/ 732°C. The octane number is 120; it can inflame having a share of 5.3 to 15% in air. Methane has only 42.4% of the density of air and thus is lighter and may disappear in case of leakages.

Natural gas and LPG: LG carriers has proven considerable good safe ship in term of designed, constructed, maintained, manned and operated of all the merchant fleet of today. So far they have low accident record and non major has leads to release of large amounts of LG have ever occurred in the history of LG shipping. Nevertheless, there have been major concerns regarding safety of LG shipping and vivid that one catastrophic accident has the potential for serious consequential fatal and environmental damage. Therefore it became imperative to use IMO Goal-based and risk based instruments to quantify a baseline risk level to identify and evaluate alternative risk control options for improved safety. Toward zero accident and zero, incident, apart from normal SOLAS standards for all ships, there is additional international regulation/Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk this include The IGC Code. This Code is applicable to

Liquefy gas carriers which are made mandatory under the SOLAS Convention. Thus, Risks associated with LPG ships encompass the following areas:

- Loading
- shipping in special purpose vessels
- Unloading at the receiving terminal.
- Third party risks to people onshore or onboard

NG shipping industry is undergoing considerable changes, e.g. an expected doubling of the fleet over a 10-year period, emergence of considerable larger vessels, alternative propulsion systems, new operators with less experience new trading route, offshore operations and an anticipated shortage of qualified and well trained crew to man Liquefies gas carriers in the near future. With this development, there is tendency for gas shipping to experience an increasing risk level in the time to come. Most IMO previous rules were made on reaction basis, in this age of knowledge employment of the new philosophy to design construct and operate based on risk and considering holistic factors of concern for sustainability and reliability remain a great invention of our time to save LPG ship and shipping.

Maritime regulation: The International convention for the Safety of Life at Sea (SOLAS) is the fundamental IMO instrument that deal with regulation requirement for basic construction and management for all types of ships. It covers areas like are stability, machinery, electrical installations, fire protection, detection and extinction systems, life-saving appliances, Surveys and inspections, SOLAS also contains a number of other codes related to safety and security that applies to shipping in general. Examples of these are the Fire Safety Systems Code (FSS Code), the International Management Code for the Safe Operations of Ships and for Pollution Prevention (ISM Code) and the International Ship and Port Facility security Code (ISPS Code). These codes imply requirements aiming at enhancing the safety on Liquefy Gas (LG) shipping activities as well as shipping in general [61,62].

Classification society rules apply for structural strength while special code for ships carrying liquefied gas included in the SOLAS regulations the IGC code. Other IMO regulations pertaining to safety are contained in the International convention on Load Lines which addresses the limits to which a ship may be loaded, the International Convention for the Prevention of Collisions at Sea (COLREG) addressing issues related to steering, lights and signals and the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW Convention) which addresses issues related to the training of crew. The International Convention for the Prevention of Pollution from Ships (MARPOL) addresses issues related to marine and air pollution from ships. These regulations are applicable to all ships as well as LPG ships. The issue of global warming has initiated MARPOL annex VI, was given preferential acceptance beyond tacit procedure and there is indication that more will follow [63].

Maritime regulations for liquify gas regulation: IMO regulation for safety regarding carriage of gas was never specifically for LNG, CNG or LPG carriers. However safety regulations exist in order to ensure the LPG ships are safe. Thus Gas carriers need to comply with a number of different rules that are common to all ship types, as well as a set of safety regulations particularly developed for ships carrying liquefied gas and the their crew as well as site selection and design of LG terminals. This include issues relating to control of traffic near ports, local topology, weather conditions, safe mooring possibility, tug capability, safe distances and surrounding industry, population and training of terminal staff. These considerations contribute to enhance the safety of LPG shipping in its most critical phase, i.e. sailing in restricted waters or around terminal and port areas. The IGC code prescribes a set of requirements pertaining to safety related to the design, construction, equipment and operation of ships involved in carriage of liquefied gases in bulk. The IACS unified requirements for gas tankers were partly derived from the IGC code.

The code specifies the ship survival capability and the location of cargo tanks. According to the type of cargo, a minimum distance of the cargo tanks from the ship's shell plating is stipulated in order to protect the cargo in case of contact, collision or grounding events. Thus the code prescribes requirements for ships carrying different types of liquefied gas, and defines four different standards of ships, as described in Table 32. LNG carriers are required to be ships of type 2G and all LNG carriers should be designed with double hull and double bottom, while 2PG type is for LPG Ships.

Ship type	Cargo
3G	Require moderate prevention method
2G	Ship less than 150m Require significant preventive measure
2PG	Require significant preventive measure cargo are carried in C tanks
1G	Require significant maximum preventive measure

Table 32: Requirement for ship carrying liquefied gas.

The IGC code requires segregation of cargo tanks and cargo vapor piping systems from other areas of the ship such as machinery spaces, accommodation spaces, control stations; it also prescribes standards for such segregation. It provides standards for cargo control rooms and cargo pump-rooms are as well as standards for access to cargo spaces and airlocks. It defines requirements for leakage detection systems, as well as loading and unloading arrangements. Different types of cargo containment systems are permitted by the IGC code, and the two main types of containment systems in use in the world liquefied tanker fleet are membrane tanks and independent tanks. Membrane tanks are tanks which consist of a thin layer or membrane, supported through insulation by the adjacent hull structure. The membrane should be designed in such a way that thermal expansion or contraction does not cause undue stress to the membrane. The independent tanks are self-supporting in that they do not form a part of the ship's hull [64].

The IGC code defines three categories of independent tanks: Type A, B and C. Type C tanks are pressure tanks for LPG and will not be required for LNG vessels since LNG are transported at ambient pressure. Regardless of what containment system is used, the tanks should be design taking factors such as internal and external pressure, dynamic loads due to the motions of the ship, thermal loads, sloshing loads into account, and structural analyses should be carried out. A separate secondary barrier is normally required for the gas liquefied gas containment systems to act as a temporary containment of any leakage of LNG through the primary barrier. For membrane tanks and independent type a tanks, a complete secondary barrier is required. For independent type B tanks, a partial secondary barrier is required, whereas no secondary barrier is required for independent type C tanks. The secondary barrier should prevent lowering of the temperature of the ship structure in case of leakage of the primary barrier and should be capable of containing any leakage for a period of 15 days.

The code contains operational requirements related to i.e. cargo transfer methods, filling limits for tanks and the use of cargo boil-offs as fuel as well as requirements on surveys and certification. Equivalents to the various requirements in the code are accepted if it can be proven, e.g. by trials, to be as effective as what is required by the code. This applies to fittings, materials, appliances, apparatuses, Equipments, arrangements, procedures. Additional requirements regarding insulation and materials used for the cargo containment systems as well as construction and testing, piping and valving etc. are included in the IGC code. The IGC code also requires certain safety equipments to be carried onboard LPG carriers. These include ship handling systems such as positioning systems, approach velocity meters, automatic mooring line monitoring and cargo handling systems such as Emergency Shutdown Systems (ESD) and Emergency Release System (ERS). In addition, systems for vapor, fire detection, fire extinguishing (dry chemical powder) and temperature control are required.

In addition to the numerous regulations, codes, recommendations and guidelines regarding gas carriers issued by IMO, there are extensive regulations, recommendation and guidelines under international and local umbrella related to safety LPG shipping exist that undoubtedly contributing to the high safety standard and the good safety record that has been experienced for the fleet of LG carriers. E.g. standards of best practice issued by SIGTTO (The Society of International Gas Tanker & Terminal Operators) [61,65].

Traning requirement: Any person responsible for, or involved with, the operation and dispensing of LPG should have an understanding of the physical characteristics of the product and be trained in the operation of all ancillary equipment. Thus acquiring sufficient crew with the required level of experience, training and knowledge of LG are believed to be one of the major safety-related challenges to the maritime LG industry in the years to come. In addition to strict regulations on the ship itself, there are also extensive international regulations specifying the necessary training and experience of crew that operate LPG carriers. These include the international rules on training requirements are contained in regulations such as the STCW 95, ISM code, tanker familiarization training, as well as flag state or company specific training requirements that go beyond these international regulations [66,67].

The competence level of Liquefied gas crew has generally been regarded as quite high compared to that of other ship types. A study presented in demonstrates that the performance score of crew onboard gas and chemical tankers are the best among cargo carrying ships, second only to that of passenger vessels. STCW 95 contains minimum training requirements for crew engaged in international maritime trade. In particular, chapter V of the STCW code contains standards regarding special training requirements for personnel on certain types of ships, among them liquefied gas carriers. One requirement for masters, Officers and ratings assigned specific duties and responsibilities related to cargo or cargo equipment on all types of tankers, e.g. LNG tankers, is that they shall have completed an approved tanker familiarization course. Such a course should have minimum cover the following topics:

- Characteristics of cargoes and cargo toxicity
- Hazards and Hazard control
- Safety equipment and protection of personnel
- Pollution prevention

The course must provide the theoretical and practical knowledge of subjects required in further specialized tanker training. Specialized training for liquefied gas tankers should as a minimum include the following syllabus:

- Regulations and codes of practice
- Advanced fire fighting techniques and tactics
- Basic chemistry and physics related to the safe carriage of liquefied gases in bulk
- Health hazards relevant to the carriage of liquefied gas
- Principles of cargo containment systems and Cargo-handling systems
- Ship operating procedures including loading and discharging preparation and procedures
- Safety practices and equipment
- Emergency procedures and environmental protection

In addition to these training requirements, masters, chief engineering officers, chief mates, second engineering officers and any persons with immediate responsibilities for loading, discharging and care in transit of handling of cargo in a LG tanker are required to have at least 3 months sea service on a liquefied gas tanker. Due to the extensive training requirements and experience level of their personnel, the maritime LNG industry claims that the crew sailing the LNG fleet are among the best in the world. However, a shortage of experienced LG crew is foreseen in the near future especially with the expected growth of the LPG fleet.

Transportation of LPG inland Water: LPG and CNG and LNG are next in line of alterative for transportation to gasoline because of their associated environmental benefits including reduction of GHGs. Thus, it is more useful for countries with natural gas resources and a relatively good gas distribution system. LPG has been explored in the 1930s but its used has been slowed because of favorable economy of petroleum. However, the current threat of climate change has increased the focus on alternative transport fuels which include. Countries with programmes on the use of CNG and LPG as a transport fuel include the USA, Canada, UK, Thailand, New Zealand,Argentina and Pakistan [58,59] CNG and LPG are used in both private vehicles and transport fleets. It is estimated that about 250 million vehicles are using this fuel worldwide, and its use is on the increase, representing 2% of total global transport fuel use. The advantages of using LPG are:

- Environmental friendliness
- reduced engine maintenance cost
- Improved engine and fuel efficiency

However limitations are the following:

- Storage containment
- High cost of conversion
- Need for high skill operator

Each category of this required thorough, holistic risk, goal based design and operability assessment for safety, reliability and protection of environment.

Environmental concern a driving force for beyond compliance policy

Over the last decade, each passing years has been augmented concerned about issue of environment importance in design, construction, operation and beneficial disposal of marine articraft. The overriding force is increasing the resources of the planet that we live and that only a few are renewable. This accumulated to production that has elements of long-term sustainability of the earth. Precipitated effect over the year has call for public awareness and translated into impact through these the following manners:

Regulations: Public pressure on governmental and non-governmental organization regulation due to untold stories of disaster and impact, the public is very concerned and in need of fact that if the quality of life of people enjoy is to be sustained, for them and the future generation then the environment must be protected. conspicuous issue, expertise and finding of regulations make them to go extra length on unseen issue, contrasting between the two, while commercial force act on hat will be forth problems.

Ship concept design: Is very important in shipping and it account for 80 percent of failure, therefore compliance and making of optimal design has a great impact in ship whole life cycle. The impact of environment in ship design is very difficult because of large numbers of uncertainties. Environmental impact hat need to be taken into considerations in concept design can be classified into the following.

Operations: Considering limiting life cycle of ships at estimate of 25 years, issues relating to the following are equally not easy to quantify in design work, even thus a lot of research effort has been set on move on this, but the call of the day require allowable clearance and solution to be given to the following: Known emission, Accidental, Ballast waste, Coating.

Commercial forces: Where company that or product that operate in unenvironmental friendly way, people are prone to spurn the companies products and service, there fore having impact on company return on investment.

Construction and disposal: Use of meticulous scantling and factors worth consideration with the ship at the end of her life cycle.

Shipboard environmental protection should Pollution Prevention (P_2) or Pollution Control. Pollution Prevention uses fewer environmentally harmful substances and generates less waste on board. Pollution Control: Increase treatment, processing, or destruction of wastes on board. The basic P_2 principles follow: Eliminating the use of environmentally harmful chemicals and reducing the amount of waste we generate on board is often better that treating it on board. Typical environmental green house gas release from different prime movers is shown in Table 33.

Emission	LPG	Gasoline	Diesel
Cox	1	10.4	1.2
HC	1	2.0	1.2
NO	1	1.2	1.1
PM	neg	present	Very high
SOx	neg	neg	Very high

Table 33: Environmental performance.

Emission is inherent consequence of powered shipping, Fuel oil burning as main source, Continuous combustion machineries-boilers, gas turbines and incinerators. And this made the following issue very important

- Worldwide focus of fuel-> Exhaust gas emission law by IMO and introduction of local rules
- Emission limits driving evolution to development and adaptation to new technology
- Solution anticipated to maintenance of ship life cycle at average of 25 years
- Focus is currently more on, NOx and SOx-HC, COx and particulate will soon join
- Consideration involves not only fuel use and design but also operational issues.

Environmental parameters	Environmental demand
Ship design	Need for longer safe life cycle
Construction	High worker safety standards, low energy input
Emission	Minimum pollution and emission, Minimum Sox, Nox and Cox, PMs-Zero discharge
Scrapping	Zero harmful emission
Operation waste	Efficient maneuverability
Energy	Maximum fuel efficiency
Antifouling	Harmless
Ballast water	Zero biological inversion or transfer of alien species
Sea mammal interaction	Maneuverability capability
Accident	Able officer, ship structure, integrity
Fire	Harmless
Wave wash of high speed marine	Zero inundation and spray a shore

Table 34: Environmental demand for ships.

Table 34 below shows the environmental regulatory demand of out time for ships that need to be considered in design and operation of LPG ships.

Hybrid use of High Level Objective Based and Safety Risk Based Design towards Beyond Compliance

It is clear that the shipping industry is over killed with rules and recent environmental issues are have potential to initiate new rules, this made firms to selectively adopt beyond compliance policy that are more stringent than the required extant law due to. Beyond compliance policy are mostly intra firm process which could be power based or leadership based. It draw insight from institutional theory, cooperate social performance perspective, and stakeholder theory that relate to internal dynamic process. While external forces create expectation and incentive for manager, intra firm politics influence how managers perceive, interpret external pressure and act on them [68,69] Policy towards beyond compliance fall into 2 categories:

- Whether they are now required by law but they are consistent with profit maximization.
- Requirement by law and firm are expected to comply by them.

Towards sustainable reliability, it is preferable to use stochastic and probabilistic methods that could help improve in the existing methodology this method involve absolutism that will cover all uncertainty complimented by historical and holistic matrix investigation. Hybridizing models is also a plus for the best solution of sustainable maintenance of navigation channel. Beyond compliance towards meeting required safety level and life cycle and environmental protection required systematic employment of hybrid of OBS and RBS systems. Below is the general step of RBS and OBS which can be apply for above described characteristic of LPG Ships.

Components of goal based standards

Objective Based Standards (OBS) are ship safety standards comprising five tiers (Figure 71):

Level I: Consists of goals expressed in terms of safety objectives defined by risk level.

Level II: Consists of requirements for ship features/capabilities, defined by risk level, that assure achievement of ship's safety objectives.

LEVEL III: Here Tier IV and V are to be verified for compliance with Tier II.

Level IV: Consists of rules, guidelines, technical procedures and programs, and other regulations for ship designing and ship operation needs, fulfillment of which satisfies ship's feature/capability requirements.

Level V: Consists of the code of practice, safety and quality systems that are to be applied to guarantee the specified rules by quality level.

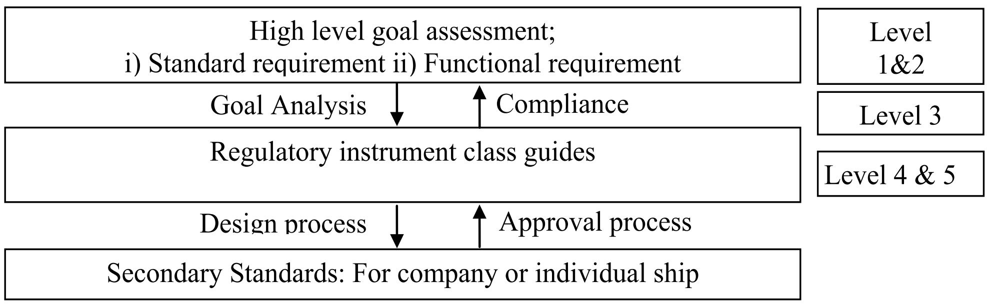


Figure 71: High level Goal Based Assessment.

Sustainable risk assessment: Sustainability remain a substantial part of assessing risk and life cycle of ships however, they are very complex and require long time data for accurate. Environmental risk and Environmental Impact Assessment (EIA) procedure is laid out by various environmental departments and will continue to remain similar except that the components of risk area cover different uncertainty to sustain a particular system are different. EIA has been a conventional process to identify, predict, assess, estimate and communicate the future state of the environment, with and without the development in order to advise the decision makers the potential environmental effects of the proposed course of action before a decision is made. RBS is improvised version of EIA where holistic consideration, community participation, expert rating, cost benefit analysis and regulatory concerned are core part of the philosophy leading to reliable decision making and sustainable system design and operation. In risk assessment, serenity and probability of adverse consequence (HAZARD) are deal with through systematic process that quantitatively measure, perceive risk and value of ship using input from all concerned waterway users and experts [69,70].

RISK = Hazard x Exposure (an estimate on probability that certain toxicity will be realized).

While hazard: Anything that can cause harm (e.g. chemicals, electricity, natural disasters). Severity may be measured by:

- No. of people affected
- Monetary loss
- Equipment downtime
- Area affected
- Nature of credible accident
- Risk ranking index according to level of risk the tables bellow show an example of risk matrix (Table 35) with assignments of risk level identifies by number index.

			Consequence Criteria				
			1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
Likelihood	A -	The consequence is almost certain to occur in most circumstances	Medium (M)	High (H)	High (H)	Very High (VH)	Very High (VH)
	B -	The consequence is likely to occur frequently	Medium (M)	Medium (M)	High (H)	High (H)	Very High (VH)
	C -	Possible and likely for the consequence to occur at some time	Low (L)	Medium (M)	High (H)	High (H)	High (H)
	D -	The consequence is unlikely to occur but could happen	Low (L)	Low (L)	Medium (M)	Medium (M)	High (H)
	E -	The consequence may occur but only in exceptional circumstances	Low (L)	Low (L)	Medium (M)	Medium (M)	High (H)

Table 35: Risk level matrix.

Risk management is the evaluation of alternative risk reduction measures and the implementation of those that appear cost effective where Zero discharge = zero risk, but the challenge is to bring the risk to acceptable level and at the same time, derive the max Benefit [64].

Components of system based safety risk assessment

System based safety assessment targets: Iidentification of potential hazard scenarios and major impact to ship Shipping and ship design which could lead to significant safety or operability consequences as well recent call for policies chance and procedural major effects Verification of current design, construction and operations ensure that risk from identified scenarios meet risk acceptability criteria.

If not, to recommend additional RBA process and available technology for control and protection that can reduce risk to suitable level.

RBA Steps:

Step 1: HAZID

The HAZID (step 1) should be conducted a in a technical meeting including brainstorming sessions, from various sectors within the LPG industry, i.e. ship owner/operator, shipyard, ship design office/maritime engineering consultancy, equipment manufacturer, classification society and research centre/university. Common identifiable hazards are:

- Emission to air, water and soil
- Shipboard cargo tank and cargo handling equipment
- Storage of tanks and Piping
- Safety Equipments and Instruments
- Ruder failure in inland water
- Crew fall or slip on board
- Fault of navigation equipments in inland water
- Steering and propulsion failure
- Collision with ship including passing vessel hydro dynamic effects
- Terrorist attack or intentional incident
- Potential Shortage of crew
- Navigation and berthing procedure

The results from the HAZID should be recorded in a risk register stating total number of hazards, different operational categories. The top ranked hazards according to the outcome of the HAZID can be selected and given respective risk index based on qualitative judgment by the HAZID participants from diverse field of expert. It should emphasize on the study of existing situations and regulations including policies in place, present performance, flaws and survey on parties feeling on acceptability and procedures.

STEP 2: Hazard analysis

The risk analysis (step 2) comprises a thorough investigation of accident statistics for liquefy gas carriers as well as risk modeling utilizing event tree methodologies for the most important accident scenarios, based on the survey of accident statistics and the outcome of the HAZID leading to generic accident scenarios recommendation for further risk analysis. Figure 72 shows formal safety assessment steps.

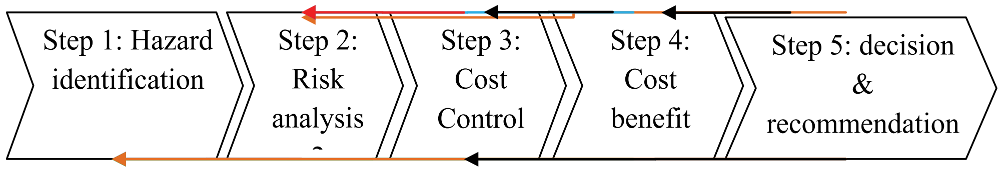


Figure 72: Risk assessment and analysis steps.

The risk analysis essentially contains two parts, i.e. a frequency assessment and a consequence assessment. The frequency assessment, involve estimation of frequency of generic incidents using reasonable accident statistics derived from the selected accident scenarios which should also be compared with similar studies for liquefy gas carriers as well as other ship. The consequence assessment should be performed using event tree methodologies. Risk models can be developed for each accident scenario and event trees constructed according to these risk models utilizing accident statistics, damage statistics, fleet statistics, simple calculations modeling and expert opinion elicitation [71].

The frequency and consequence assessments provide the risk associated with the different generic accident scenarios which can be summarized in order to estimate the individual and societal risks pertaining to liquefy gas carrier operations and design. Based on available accident statistics and results from the HAZID, eight generic accident scenario umbrellas that required deep analysis are:

- Collision
- Fire or explosion
- Grounding
- Contacts
- Heavy weather/loss of intact stability

- Failure/leakage of the cargo containment system
- Incidents while loading or unloading cargo LPG
- Emission ship power sources

The first five generic accident scenarios are general in the sense that they involve all types of ships; wile 6 and 7 accident scenarios are specific to gas carriers and 8 concerned new environmental issue driving compliance and technology for all ships. Selected accident scenarios to investigate frequency assessment could provide a sufficiently accurate estimate of initiating frequencies for the eight selected accident scenarios. Figure 73 shows risk model for explosion case.

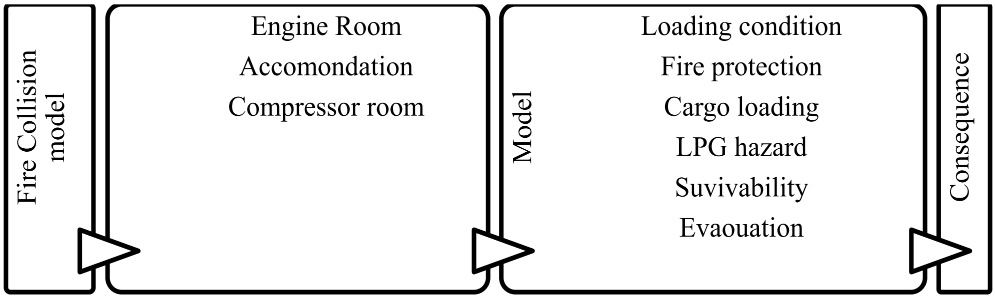


Figure 73: Risk model for explosion scenario.

Identification of accident scenario that is significant to risk contribution should consider use of:

- Holistic risk assessment of major treat using RBA and OBS oodel including application of stochastic.

Probabilistic and deterministic methods to increase reliability and reduce uncertainties as much as possible this including using tool comprising foreseeable scenarios and scenario event, such tolls are:

Accident modeling model

- Estimation of risk, accident frequency and consequences

Step 3: Risk control

Risk control measures are used to group risk into a limited number of well thought out practical regulatory options. Consideration should focus on:

- Specification of risk control measures for identified scenarios
- Grouping of the measures into possible risk control options using
- General approach: which provides risk control by controlling the likelihood of initiation of accidents, and may be effective in preventing several different accident sequences and
- Distributed approach: which provides control of escalation of accidents, together with the possibility of influencing the later stages of escalation of other, perhaps unrelated, accidents. And this followed by assessment of the control options as a function of their effectiveness against risk reduction.

Step 4: Cost Benefir Assessment (CBA)

Risk-Cost Benefit analysis to deduce mitigation and options selection Proposed need for new regulations based on mitigation and options.

CBA quantification of cost effectiveness that provide basis for decision making about RCO identified, this include the net or gross and discounting values.

Cost of equipment, redesign and construction, documentation, training, inspection maintenance and drills, auditing, regulation, reduced commercial used and operational limitation (speed , loads)

Benefit could include, reduced probability of fatality, injuries, serenity and negative effects as well as on health, severity of pollution and economic losses

Step 5: Decision making

This step involves:

- Discussion of hazard and associated risks
- Review of RCO that keep ALARP
- Comparison and rank RCO based on associated cost and benefit

Specification of recommendation for decision makers output could be use for beyond compliance preparedness and rulemaking tools for regulatory bodies towards measures and contribution for sustainability of the system intactness, our planet and the right of future generation. In order to select between alternative technical or regulatory solutions to specific problems the first three RBA steps (HAZID, risk assessment, RCOs) can fit into the development of high-level goals (Level 1) and functional requirements (Level 2) of OBS. Equally, the last three steps (RCOs, CBA, and Recommendations) could feed into Level IV and V of OBS

Uncertainty: Uncertainty will always be part of our activities because of limitation of knowledge of unseen in real world settings, issues associated with uncertainty are normally.

- Influences on recovery process
- Test of new advancements
- Influence on policy
- Address system changes over time
- services & resources

Estimating uncertainty including further validation, policy issues and rating could be obtained through the relation:

$$R(P1c) = R(E1) \times W(E1,P1) + R(E2) \times W(E2,P1) + R(E4) \times W(E4,P1)$$

Where R = rating, E = environmental factor, P = Policy factor

Uncertainty is necessary because of highly variable nature of elements and properties involved with the situation require simulate of extreme condition and model using combination mathematical modeling and stochastic techniques while considering all factors in holistic manner that cover:

- Risk areas and assessment: taking all practical using historical data's and statistics that include all factors. Public health (people > other species)
- Mitigation of risk assessment and risk areas: This involves making permanent changes to minimize effect of a disaster Immediacy: (Immediate threat>delayed threats)
- Panel of expert: Reach out to those who are capable to extend hand and do the right thing at the risk area Uncertainty (More certain-> less certain)
- Community participation: Educate all concern about the going and lastly place firm implementation and monitoring procedure. For adaptability (Treatable-> untreatable)
- Emergency response: provide monitoring and information facilities and make sure necessary information is appropriately transmitted and received by all.

Risk acceptability criteria: The diagram below gives overall risk reduction areas identification and preliminary recommendation, In order to assess the risk as estimated by the risk analysis, appropriate risk acceptance criteria for crew and society for LPG tankers should be established prior to and independent of the actual risk analysis. The overall risk associated with LPG carriers should be concentrated in the reduction desired areas ALARP, where cost effective risk reduction measures should be sought in all areas. Three areas or generic accident scenarios where which together are responsible for about 90% of the total risk are: Collision, grounding and contact, and they are related in that they describe situation where by the LPG vessel can be damaged because of an impact from an external source support inland water like vessel or floating object, the sea floor or submerged objects, the quay or shore or bad weather. Figure 74 and 75 show prescription risk acceptability analysis graphs.

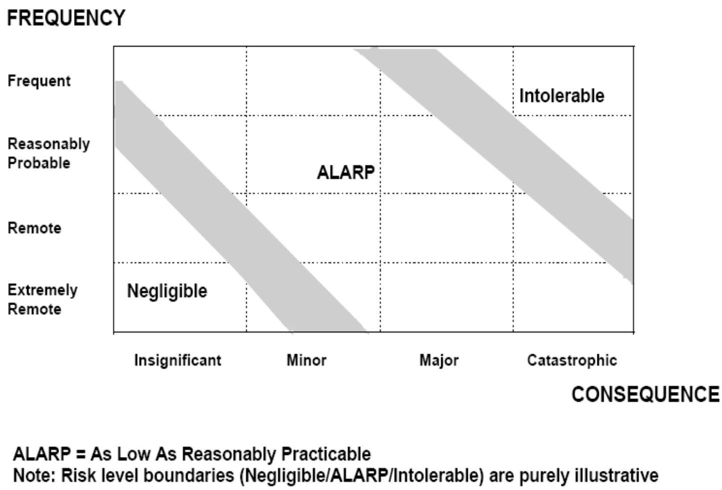


Figure 74: ALARP diagram-Source.

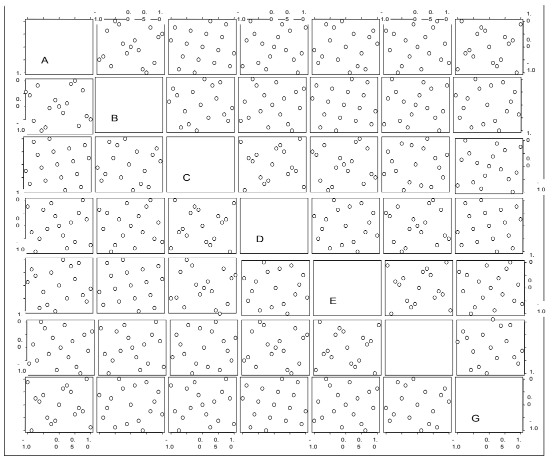


Figure 75: Matrix plot analysis of system ALARP.

By studying the risk models associated with these scenarios, four sub-models in particular stands out where further risk reduction could be effective. These are the accident frequency model, the cargo leakage frequency model, the survivability model and the evacuation model. Particularly, related to collision, grounding and contact, it is recommended that further efforts in step 3 of this FSA focus on measures relating to:

Navigational Safety Improvements

- Maneuverability: Improved maneuverability Extended use of tugs might reduce the frequency of contact and grounding events near the terminals.
- Collision avoidance: i.e. warning boats in busy waters to clear the way for the LPG carrier.
- Cargo protection: Measures to prevent spillage through enhancing the cargo containment system's ability to maintain its integrity
- Damage stability: Reducing the probability of sinking though enhancement of survival capabilities in damaged condition

Evacuation arrangements and associated consequence through improvements relating to evacuation procedures, escape route layout or life saving appliances. Figure 76 shows the CBA balancing process curve for sustainable design.

Risk control options step 3 can be identified and prioritized at technical workshops, such meting could consider identification and selection of risk control options for further evaluation and cost benefit assessment. This part of the FSA also contained a high-level review of existing measures to prevent accidental release of gas.

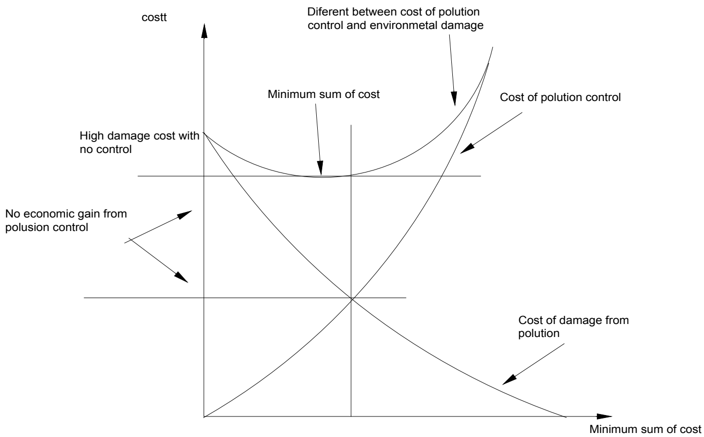


Figure 76: Cost Benefit Analysis.

$$Accepatblequotient = \frac{Benefit}{Risk\ /_{\mathrm{Cost}}} \quad (1)$$

The economic benefit and risk reduction ascribed to each risk control options should be based on the event trees developed during the risk analysis and on considerations on which accident scenarios would be affected. Figure 76 shows cost benefit analysis representative graph. Estimates on expected downtime and repair costs in case of accidents should be based on statistics from shipyards.

Beyond compliance ship design

Existing design tools cannot, at least with any degree of reliability, be used to design a vessel to operate will ensure environmental reliability for LPG ships and operation in shallow or restricted waters. This is because of the extreme on-linearity of hull and propulsion characteristics under these conditions. In general, naval architects and marine engineers are educated and equipped with knowledge, skills, design processes that permit continuous checking balancing of constraints and design tradeoffs of vessel capabilities as the design progresses.

The intended result of the process is the best design given the basic requirements of speed, payload, and endurance. Focus is not placed on top down model of generic design based on risk where all areas of concerned are assessed at different stages of design spiral as well as risk of environmental consequence for risk involved in operability in restricted water. Operational wise, recent time has seen real attempt to fully integrate human operational practices with vessel design.

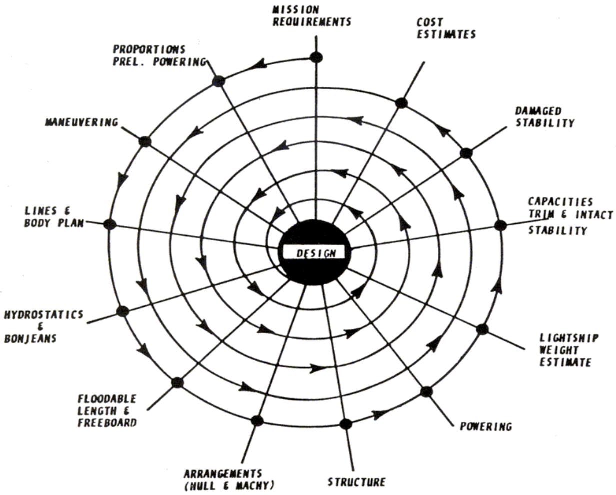


Figure 77: Ship Design Spiral.

Evolving simulation technology, however give hope for assessment of extreme engineering to mitigate extreme condition as well as envisaged uncertainty. Incorporating risk assessment and goal based design for environmental protection and accident prevention as an important part of ship design spiral (shown in Figure 77) for LPG ship a necessary step to enabling proper tradeoffs in vessel design for reliability and other demands of time. The result is that design decisions that can compromise environment and collision are decided in favor of other factors. Only consideration of the full range of ship and terminal design and human factors relationships that affects LPG ships will produce an efficient and safe environmental friendly marine transportation system of LPG. Now that the new issue of environment is around, then we have to squeeze in more stuff in the spiral.

In shipping and associated industries, ship protection and marine pollution are respectively interlinked in term of safety and environment, conventionally; ship safety is being deal with as its occurrence result to environmental problem. Likewise, for many years, less attention has been given to ship life cycle, material properties, and frequency matching with the environment has resulted to corrosion. Also ship scraping, and what happen to the environment after ship scraping, yes a lot of recycling, but little or no attention is given to the residual material that find their ways to pollute the clean beautiful sea. Other areas of concern are channel ship design criteria ships, controllability in dredged channels and maneuverability as a consideration in the Design Process. All in all, preventive and control incorporating sensible measures in ship design can only be optimized method and give us confidence on our environment. Focal areas that are will need revolutionary changes in ship design for LPG Ships are:

- Material selection to withstand structural, weight, economical lifecycle anti-corrosion and fouling
- Ascertain the IGC requirements for LPG carriers and special design considerations
- Consideration of critical load cases for each structure component as well as Corrosion
- Design considerations and general requirements Internal cargo pressures according to the IGC Code
- Vertical supports, anti-rolling keys, anti-floating keys and anti-pitching keys
- Standard design load cases for yielding and buckling Standard design load cases for fatigue. Acceptance criteria Fatigue strength assessment
- Thermal stress analysis around supports
- Incorporating ship simulation at early stage of ship design
- Validation of applied loadings and the responses to structural scantly towards withstanding structural function, reliability, integrity, weight, economical lifecycle using Structural FE Analysis
- Incorporation manoeuvring ship simulation at early stage of design iteration

Beyond compliance cargo tank design: Pressure vessel is storage tank designed to operate at pressures above 15 p.s.i.g. Common materials held and maintained by **pressure vessels** include air, water, nitrogen, refrigerants, ammonia, propane, and reactor fuels. Due to their pressurizing capabilities, they are often used to store chemicals and elements that can change states. For this reason gas property is important in their design, the walls of pressure vessels are thicker than normal tanks providing greater protection when in use with hazardous or explosive chemicals. Important parameters to consider when specifying pressure vessels include the capacity, the maximum pressure and the temperature range.

The capacity is the volume of the pressure vessel: The maximum pressure is the pressure range that the vessel can withstand.

The temperature ranges indicates the temperature of the material that the container can withstand Built in temperature control system. This helps to keep volatile chemicals in inert states. At times it may also change the state of the chemicals to make transportation easier.

Pressure vessel with temperature controls have gauges to allow for reading of internal pressures and temperatures. These gauges are available with a variety of end connections, levels of accuracy, materials of construction, and pressure ranges. There are mainly two types of pressure vessels:

Spherical pressure vessel: These pressure vessels are thin walled vessels. This forms the most typical application of plane stress. Plane of stress is a class of common engineering problems involving stress in a thin plate. It can also be called as simplified 2D problems.

Cylindrical pressure vessel: This vessel with a fixed radius and thickness subjected to an internal gage pressure, the vessel has an axialsymmetry. Analyses of LPG tanks design required of advantage of finite element modeling with fluent and other CFD software using static, dynamic, thermal and nonlinear analysis. To prove the structural integrity of the tank designs for structural and seismic loading as well as assesses leakage and burn-out scenarios.

Tank analyses should include:

- Leakage and double walled piping modeling
- Prestress/post-tensioning and Burn-out modeling
- Relief valve heat flux modeling Static analysis
- Wind loading and modal and seismic analysis
- Temperature modeling prediction of stresses loading as well as other environmental safety
- Stress and thermal analysis of marine loading arm.

Beyond compliance HAZOP and FMEA: Operability must follow Hazards associated with LPG ships. HAZOP and FMEA risk assessment following FSA procedure recommended. Beside this the following operational requirement are expected to exercise all the time for all operation activities

Gas equipment: Equipments associated with gas works that require regular look after are: Gas dryer, heat exchanger, storage and container, gas reactors, gas compressor type, gas liquefier, dust filter, air separation column, filling manifold distillation column. Expansion engines suction filter, after cooler, moisture absorber air compressor.

Use of Personal Protective Equipment (PPE): Owing to its rapid vaporisation and consequent lowering of temperature, LPG, particularly liquid can cause severe frost burns if brought into contact with the skin. P.P.E appropriate for use with LPG must always be worn when the refuelling operation is taking place.

- Neoprene gloves, preferably gauntlets (or similar, impervious to LPG liquid).
- Safety gear- footwear, Goggles or face shield. Long sleeved cotton overalls.

Housekeeping: Housekeeping is one of the most important items influencing the safety of the Color Gas Installation.

- No smoking no naked lights or other sources of ignition, including the use of mobile phones, pagers, or radio transmitters, are permitted in the vicinity of the installation.
- Do not ignore the hazard signs or remove them. (or put your emergency sign here).
- The area must be kept free from long grass, weeds, rubbish, and other readily ignitable or hazardous materials.
- All emergency exits and gangways to be kept clear at all times.

Gas storage: Gas storage facility is a vital factor in off-setting seasonal fluctuations in demand and safeguarding gas supplies at all times. Gas storage plays a vital role in maintaining the reliability of supply needed to meet the demands of consumers. LPG gases are explosive and are stores carefully and properly with extra attention and effort to avoid any kind of injury. The following are important hazard risk measured to follow for gas storage:

- Transportable gas containers should be stored in well defined areas and should be segregated according to the hazard presented by the contents.
- Contents of cylinders should be easily identifiable.
- Persons involved should receive training regarding handling of cylinder, potential risks, hazards from cylinder and contents.
- Gases can be stored in pressure vessels, cylinders, trailer, vaporizer and tanks. These are stored away from flammable materials and electrical outlets.

Account should be taken of external dangers such as adjacent work operations under different managerial control or the possibility of mechanical damage due to traffic knocks. The gases should not be subjected to any sort of physical damage or corrosion. Emergency procedures should be established.

In the present times, many new next generation systems are being developed in order to cater for the growing need for operational flexibility required by various gases and gas-fired power generation customers all across the globe. The exploration, production, and transportation of gases takes time, and most of the times the gas that reaches its destination is not always needed right away, so it is injected into gas storage facilities. These gas storage facilities should have the following characteristics:

- ıLow Maintenance and easy to operate
- Trouble Free Operation
- ıSturdy Design and long operative life
- Low Working Pressure and Low Operating Cost
- Easy availability of spare parts and ıLow power consumption

First aid: Treatment must be carried out immediately by placing the casualty gently under slowly running cool water, keeping it there for at least 10minutes or until the pain ceases or cover the affected parts with light, dampened or wet material. Encourage the affected person to exercise any fingers, toes or legs that are affected to increase circulation. In severe cases, tissue damage will take place before medical aid can be obtained. Seek professional medical treatment as required.

Inhalation: LPG vapor is mildly narcotic, inhalation of high concentrations will produce anesthesia. Prolonged inhalation of high concentrations will cause asphyxiation. The emergency treatment for inhalation is to move the casualty to fresh air, keeping them warm and at rest. In chronic cases, where there is a loss of consciousness give oxygen or if breathing ceases give artificial respiration. Professional medical treatment should be sought as required.

Eyes: Immediately flush eyes with plenty of water for at least 15minutes. Hold eyelids apart while flushing to rinse the entire surface of eye and lids with water. Seek medical attention immediately.

Skin: A strong refrigerant effect is produced when liquid LPG comes into contact with the skin. This is created by the rapid evaporation of the liquid and it can cause severe frostbite, depending on the level of exposure.

Emergency preparedness

In the event of fire: The fact that LPG is used as a safe and valuable heating source in millions of homes show that there are chances to controlling and preventing a fire involving LPG. To minimize the possibility of outbreak of fire, it is of key importance to provide good plant design and layout, ensure sound engineering and good operating practice, and provide proper instruction and training of personnel in routine operations and actions to be taken in an emergency. Actions required are:

- Shut all valves on tank or cylinders and emergency control valve outside the building by turning clockwise.
- Call the Fire Service and refer to presence of LPG tank.
- Keep tank cool by water spray, if possible.

Gas leakage: Damaged vessels and cracks can result in leakage or rupture failures. Potential health and safety hazards of leaking vessels include poisonings, suffocations, fires, and explosion hazards. Rupture failures can be much more catastrophic and can cause considerable damage to life and property. The safe design, installation, operation, and maintenance of pressure vessels in accordance with the appropriate codes and standards are essential to worker safety and health. Actions required are:

- Shut the emergency control valve outside your building
- Extinguish all sources of ignition.
- Shut all cylinder valves or the gas isolation valve on top of the tank
- Do not operate electrical switches.
- Open all doors and windows. Ventilate at low level as LPG is heavier than air.

Above all Appliances should be serviced according to the manufacturer's recommendations by a competent person

Environmental technology and beyond compliance performance prospect

Development real time simulation helps in the mitigation most of the accident and cover issues of uncertainty. Development in automation technology help in installation of emergency shut down mechanism advent of advance communication technology further give hope for improvise protection prevention and control Prospect of container unitized LPG ships in inland water.

Novel design of inland water craft to provide solution to issue of bigger ship inability to maneuver in inland water.

In line with Global warming, since air emission is linked to machineries emerging new technology for efficient and low air pollution power source for ships including LPG Ships are:

- Alternative energy
- Alternative fuel and dual fuel engines
- Infusion of water mist with fuel and subsequent gas scrubbing units for slow speed engines
- Additional firing chamber
- Potential for gas turbine complex cycle
- Potential for turbocharger diesel engine
- Compound cycle with gasified fuel, external compressor, combustion with pure oxygen
- Exhaust after treatment for medium speed engines

Conclusion

In today, environmentally conscious world there is already so mush pressure on stake holder designer operator's trainer and builders in shipping industry, especially ship carrying flammable gases like LPG/CNG to avoid accident and incident and the consequence of which could lead to catastrophic long term environmental disaster. Potential for more laws prevent and put necessary control in place is evident. However, the use of available and new technology in an innovative age of information technological and knowledge that has built through research activities related to speed, safety, reliability, miniaturization, cost, mobility and networking in most industries. Integrative utilization of which could facilitate optimization our system at design, operation and other factors of life cycle accountability process in order to come up with sustainable system. The answer to this lies on beyond compliance policy using IMO FSA and GBS tool in hybrid as required to meet future law requirement and to aid effective development of rules that satisfy all concern. Functional requirements for liquid gas carrier design and operations in restricted water can be adequately developed from design, operation, human elements and construction point of view using adequate technical background as well as ergonomic design principles.

6. Risk and Reliability Based Multi- Hybrid Alternative Energy for Marine System: The Case of Solar, Hydrogen and Convention Power Steam Energy for Sustainable Port Powering

Abstract

Sources of alternative energy are natural. There has been a lot of research about the use of free fall energy from the sun to the use of reverse electrolysis to produce fuel cell. For one reason or the other these sources of energy are not economical to produce. Most of the problems lie on efficiency and storage capability. Early human civilization use nature facilities of soil, inland waterways, waterpower which are renewable for various human needs. Modern technology eventually replaces renewable nature with non renewable sources which requires more energy and produces more waste. Energy, Economic and Efficiency (EEE) have been the main driving force to technological advancement in shipping. Environmental problem linkage to source of energy poses need and challenge for new energy source. The paper discuss risk based iternative and integrative sustainability balancing work required between the 4 Es in order to enhance and incorporate use of right hybrid combination of alternative energy source (solar and hydrogen) with existing energy source (steam diesel or steam) to meet marine system energy demands (port powering). The paper will communicate environmental challenges facing the maritime industry. Effort in the use of available world of human technocrat to integrate sources of alternative energy with existing system through holistic proactive risk based analysis and assessment requirement of associated environmental degradation, mitigation of greenhouse pollution. The paper will also discuss alternative selection acceptable for hybrid of conventional power with compactable renewable source solar/hydrogen for reliable port powering. And hope that the Decision Support System (DSS) for hybrid alternative energy communicated in this paper to improve on on-going quest of the time to balance environmental treat that is currently facing the planet and contribution to recent effort to preserve the earth for the privilege of the children of tomorrow.

Keywords: Alternative energy; energy; hybrid; port; power; sustainability;

Introduction

Scale, transportation, language, art, matter and energy remain keys to human civilization. The reality of integration of science and system lies in holistically investigation of efficiency of hybridizing alternative energy source with conventional energy source. This can be achieved with scalable control switching system that can assure reliability, safety and environmental protection. Option for such sustainable system is required to be based on risk, cost, efficiency benefit assessment and probabilistic application. Green house gas (GHG) pollution is linked to energy source. Large amount of pollution affecting air quality is prone by reckless industrial development. GHG release has exhausted oxygen, quality of minerals that support human life on earth, reduction in the ozone layer that is protecting the planetary system form excess sunlight. This is due to lack of cogent risk assessment and reliability analysis of systems before building. Moreso, because conventional assessment focus more on economics while environment and its associated cycle is not much considered [72, 73]. Human activities are altering the atmosphere, and the planet is warming. It is now clear that the costs of inaction are far greater than the costs of action. Aversion of catastrophic impacts can be achieved by moving rapidly to transform the global energy system. Sustainability requirement that can be solved through energy conservation (cf. IPCC) are energy and associated efficiency, development, environment, poverty. Stakeholder from government's consumers, industry transportation, buildings, product designs (equipment networks and infrastructures) must participate in the decision work for sustainable system.

Recently the marine industry is getting the following compliance pressure regarding environmental issues related to emission to air under IMO MARPOL Annex 6. A world without port means a lot to economy transfer of goods, availability of ships and many things. Large volume of hinterland transportation activities import tells a lot about intolerant to air quality in port area. Adopting new energy system will make a lot of difference large number of people residing and working in the port. Most port facilities are powered by diesel plant. Integrating hybrid of hydrogen and solar into the existing system will be a good way for the port community to adapt to new emerging clean energy concept. Hybrid use of alternative source of energy remains the next in line for the port and ship power. Public acceptability of hybrid energy will continue to grow especially if awareness is drawn to risk cost benefit analysis result from energy source comparison and visual reality simulation of the system for effectiveness to curb climate change contributing factor, price of oil, reducing treat of depletion of global oil reserve. Combined extraction of heat from entire system seems very promising to deliver the requirement for future energy for ports. This paper discuss available marine environmental issues, source of energy today, evolution of alternative energy due to the needs of the time and the barrier of storage requirement, system matching of hybrid design feasibility, regulations consideration and environmental stewardship. The paper also discusses holistic assessment requirement, stochastic evaluation, using system based doctrine, recycling and integrated approach to produce energy. With hope to contribute to the ongoing strives towards reducing green house gases, ozone gas depletion agents and depletion of oxygen for safety of the planet in order to sustain it for the right of future generation.

Energy, environment and sustainable development: Since the discovery of fire and the harnessing of animal power, mankind has captured and used energy in various forms for different purposes. This include the use of animal for transportation, use of fire, fuelled by wood, biomass, waste for cooking, heating, the melting of metals, wind mills, water wheels and animals to produce mechanical work. Extensive reliance on energy started during industrial revolution. For years there has been increased understanding of the environmental effects of burning fossil fuels has led to stringent international agreements, policies and legislation regarding the control of the harmful emissions related to their use. Despite this knowledge, global energy consumption continues to increase due to rapid population growth and increased global industrialization.In order to meet the emission target, various measures must be taken, greater awareness of energy efficiency among domestic and industrial users throughout the world will be required and domestic, commercial and industrial buildings, industrial processes and vehicles will need to be designed to keep energy use at a minimum. Figure 78 shows that the use of fossil fuels (coal, oil and gas) accounted continue to increase [72,74].

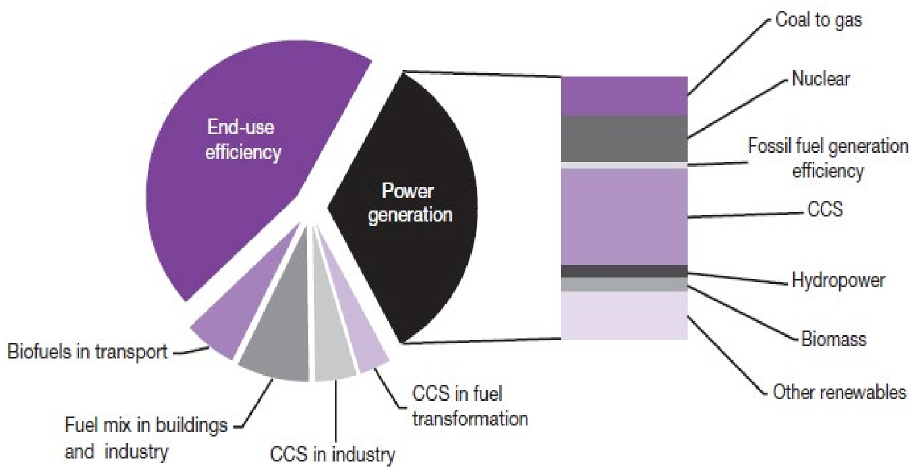


Figure 78: GHG Emissions Reductions through 2050, by Consuming Sector.

Various measures must be taken to reduce emission targets.The current reliance on fossil fuels for electricity generation, heating and transport must be greatly reduced and alternative generation methods and fuels for heating and transport must be developed and used. Sustainable design can be described as system work that which enhances ecological, social and economic well being, both now and in the future. The global requirement for sustainable energy provision is become increasingly important over the next fifty years as the environmental effects of fossil fuel use become apparent. As new and renewable energy supply technologies become more cost effective and attractive, a greater level of both small scale and large scale deployment of these technologies will become evident. Currently there is increasing global energy use of potential alternative energy supply system options, complex integration and switching for design requirement for sustainable, reliable and efficient system. The issues surrounding integration of renewable energy supplies need to be considered carefully. Proactive risk based Decision support system is important to help the technical design of sustainable energy systems, in order to encourage planning for future development for the supply of electricity, heat, hot water and fuel for transportation. Renewable energy systems have intermittence source, this make assurance reliability of the supply and subsequent storage and back-up generation a necessity. Generic algorithms of the behavior of plant types and methods for producing derived fuels to be modeled, available process and manufacturer's data must be taken into consideration. Today, simulation tool for analysis that allow informed decisions to be made about the technical feasibility of integrated renewable energy systems are available. Tool that permit use of supply mix and control strategies, plant type and sizing, suitable fuel production, and fuel and energy storage sizing, for any given area and range of supply should be adopted.

Energy consumption, demand and supply: Energy is considered essential for economic development, Malaysia has taken aggressive step in recent year to face challenges of the world of tomorrow, and this includes research activities strategic partnership. one example is partnership with the Japanese Government for construction on sustainable energy power station in the Port Klang power station, Pasir Gudang power station, Terengganu Hydro-electric power station and Batang Ai Hydro-electric power station which are main supply to major Malysian port. The above enumerated power stations are constructed with energy-efficient and resource-efficient technologies. Where power station are upgraded the power station by demolishing the existing aging, inefficient and high emission conventional natural gas/oil-fired plant (360MW) and installing new 750MW high efficiency and environment friendly combined cycle gas fired power plant built at amount of JPY 102.9 billion. The combined-cycle generation plant is estimated to reduce the power station's environmental impact, raise generation efficiency and make the system more stable. The total capacity of power generation of 1,500MW is equal to 14% of total capacity of TNB in peninsula of 10,835MW and indeed this power station is one of the best thermal power stations with highest generation efficiency in Malaysia of more than 55%. The rehabilitation, the emissions of Nitride oxide (NO_x) is reduced by 60%, Sulfur dioxide (SO_2) per unit is reduced by almost 100% and Carbon dioxide (CO_2) emission is reduced by 30%. Port operation energy demands are for transportation, hot water and heat. This third generation plan can easily be integrated with alternative energy [72,75]. Table 36 shows Malaysia energy environment outlook.

Energy-Related Carbon Dioxide Emissions (2006E)	163.5 million Metric tons, of which Oil (44%), Natural Gas (41%), Coal (15%)
Per-Capita, Energy-Related Carbon Dioxide Emissions ((Metric Tons of Carbon Dioxide) (2006E)	6.7 Metric tons
Carbon Dioxide Intensity (2006E)	0.6 Metric tons per thousand $2000-PPP** 96.0 billion kilowatt hours

Table 36: Malaysia environmental review.

The energy use in all sectors has increased in recent years, most especially the energy use for transport has almost doubled it continues to grow and becoming problem. This trend is being experienced in industrialized and developing world. Energy demand for port work is supply from grids which are well established in most developed world. The method and sitting of generating conventional energy and renewable energy determine system configuration. Hierarchy systems that can be deduced from these two variables are:

- Limited capacity energy
- Limited energy plant
- Intermittent energy plant

Emerging renewable energy system: The design of integrated sustainable energy supply technology systems that are reliable and efficient for transport, heat, hot water and electricity demands can be facilitated by harnessing weather related sources of energy (e.g. wind, sunlight, waves, and rainfall). In order to provide a reliable electricity supply, reduce energy wastage and enable the energy requirements for heat and transport to be met, the outputs of these intermittent sources may be supplemented by various means [75,76]. The intermittent nature of most easily exploited sources of alternative energy remains the major problem for the supply the electricity network. This has implications for the management of this transitional period as the balance between supply and demand must be maintained as efficiently and reliably as possible while the system moves towards the ultimate goal of a 100% renewable energy supply over the next fifty to one hundred years.It important to take the of amount intermittent electricity sources that can be integrated into a larger scale electricity supply network into consideration.Excess supply could be supplied by plant run on fuels derived from biomass and waste.The renewable hybrid age require utilities, local authorities and other decision makers to be able to optimization that beat constraints, potentials and other energy requirements from port powering.The sizing and type of storage system required depends on the relationship between the supply and demand profiles.For excess amount electricity produced this could be used to make hydrogen via the electrolysis of water.This hydrogen could then be stored, used in heaters or converted back into electricity via a fuel cell later as required. Using excess electricity, this hydrogen could be produced centrally and piped to for port or produced at vehicle filling stations for haulage or at individual facilities in the port [77,78]. Alternatively, excess electricity could be used directly to fuel electric haulage trucks, recharging at times of low electricity demand or use for HVAC system or water heating for immediate use or to be stored as hot water or in storage heaters [79].

Energy supply and demand matching: Fossil fuel use for transportation and port activities has increased dramatically over the past decade, and shows little signs of abating. This has caused concern about related environmental and health effects. There is need for to develop alternatively fuel system that produces little or no pollution. The main fuels that can be used in a variety of land, sea and air vehicles are biogas in natural gas and fuel cell vehicles, biodiesel in diesel vehicles, ethanol and methanol in adapted petrol and fuel cell. Biogas can be converted to run on natural gas and in some fuel cell. It must be cleaned first to create a high heating value gas (around 95% methane, a minimum of heavy gases, and no water or other particles). Fuel cell powered engine can run on pure hydrogen, producing clean water as the only emission. Biodiesel can be used directly in a diesel engine with little or no modifications, and burns much more cleanly and thoroughly than diesel, giving a substantial reduction in unburned hydrocarbons, carbon monoxide and particulate matter. The main barriers to the implementation of alternative fuels is the requirement for a choice of fuel at a national level, the necessity to create a suitable refueling infrastructure, the length of time it will take to replace or convert existing vehicles, and the need for a strong public incentive to change [25,30,31]. Choice of conventional energy source could be:

Internal Combustion and Diesel Engines: Steam Turbines [78,80].

- Stirling Engines
- Gas Turbines

Choice of alternative energy

Fuel Cells: The principle of the fuel cell was discovered over 150 years ago. NASA has improved the system in their emission free operation for spacecraft. Recent years has also seen improvement in vehicles, stationary and portable applications. As a result of this increased interest, stationary power plants from 200W to 2 MW are now commercially available, with efficiencies ranging from 30 to 50% and heat to electricity ratios from 0.5:1 to 2:1. Fuel cell re load follower energy, the efficiency of a fuel cell typically increases at lower loadings. Fuel cell system also has fast response. This make them well suited to load following and transport applications. Fuel cell is advanced alternative energy technology with electrochemical conversion of fuel directly into electricity without intermediate stage, the combustion of fuel; hence by-pass the restriction of second law of thermodynamic the basic fuel supply in the fuel cell systems is hydrogen and carbon dioxide. The simplified fuel cell is exact opposite of electrolysis. The four basic element of the system are hydrogen fuel, the oxidant, the electrodes and the electrolyte chemicals. The fuel is supplied in the form of hydrogen and carbon dioxide which represent electrode and oxidant cathode, the electrolyte material that conduct the electric current can be acid or alkaline solid or liquid. Cycle of operation begin with hydrogen carbon dioxide to the anode, where hydrogen ion are formed, releasing a flow of electron to the cathode through the electrolyte medium. The cathodes take oxygen from the air and transform it into ion state in combination with anode electron. The oxygen carrying ion migrates back to the anode, completing the process of energy conversion by producing a flow of direct current electricity and water as a by-product.

2H2->4e- +4H+ (1)

4h+ +4e- +O2->2H20 (2)

2H2+02 -> 2H20 +Heat (3)

The fact that it is made from water has promise for its unlimited supply the fact that water is the by-product also guarantee vast reduction of pollution on earth, solving problem of green house gas release and global warming. Fuel cell system involve combination of groups of small chemical reactions and physical actions that are combined in a number of ways and a in a number of different sections of the generator. This energy source uses the principles of thermodynamics, physical chemistry, and physics. The net result is a non-polluting, environmentally sound energy source using air or even water cooling with a minimum temperature rise of 20C above ambient and no emissions. The chemicals, metals and metal alloys involved are non-regulated. The chemical reactions are encased within the process unit where they are recovered, regenerated and recycled. This process produces no discharge or emission [75,76]. Fuel cells are classified by the type of electrolyte they use, and this dictates the type of fuel and operating temperature that are required. The most commonly used fuel cell for small scale due to its low operating temperature and compact and light weight form, is the Proton Exchange Membrane Fuel Cell (PEMFC). Phosphoric Acid and Molten Carbonate fuel cells (PAFC and MCFC) are also available for larger scale applications, and require higher operating temperatures (roughly 200°C and 650°C), which means they must be kept at this temperature if fast start-up is required. All of these fuel cells may be run on pure hydrogen, natural gas or biogas. Certain PAFCs may also use methanol or ethanol as a fuel. If pure hydrogen is used, the only emission from a fuel cell is pure, clean water. If other fuels are used, some emissions are given off, though the amounts are lower due to the better efficiencies achievable with fuel cells. Table 37 shows the types of fuel cell and their characteristics [76].

Types	Electrolyte	Operating temperature
Alkaline	Potassium hydroxide	50-200
Polymer	Polymer membrane	50-100
Direct methanol	Polymer membrane	50-200
Phosphoric acid	Phosphoric acid	160-210
Molten carbonate	Lithium and potassium carbonate	600-800
Solid oxide	Ceramic compose of calcium	500-1000

Table 37: Type of electrolyte fuel cell.

Comparing the efficiency of fuel cell to other source of alternative energy source, fuel cell is the most promising and economical source that guarantee future replacement of fossil fuel. However efficiency maximization of fuel cell power plant remains important issue that needs consideration for its commercialization. As a result the following are important consideration for efficient fuel cell power plant. Efficiency calculation can be done through the following formula:

$$E_C = g\frac{G}{nF} \quad (4)$$

G= H*T *Si (5)

Where: Ec = EMF, G = Gibbs function nF = Number of Faraday transfer in the reaction, H = Enthalpy, T = Absolute temperature, S = Entropy change, I = Ideal efficiency.

Advantages of fuel cell include size, weigh, flexibility, efficiency, safety, topography, cleanliness. Mostly use as catalyst in PAFC, and however recovery of platinum from worn out cell can reduce the cost and market of the use of P ACF economical. It has cost advantage over conventional fossil fuel energy and alternative energy. Disadvantages of fuel cell are adaptation, training, and cost of disposal. Fuel cell has found application in transportation, commercial facility, residential faculty, space craft and battery.

Solar energy system: Photovoltaic (PV) solar system use silicon photovoltaic cell to convert sunlight to electricity using evolving unique characteristic of silicon semiconductor material and accommodating market price of silicon is god advantage for PV fuel cell.Silicon is grown in large single crystal, wafer like silicon strip are cut with diamond coated with material like boron to create electrical layer, through doping the elementary energy particle of sunlight photon strike the silicon cell. They are converted to electron in the P-N junction, where the p accepts the electron and the n reject the electron thus setting into motion direct current and subsequent inversion to AC current as needed. Electrical conductor embedded in the surface layer in turn diverts the current into electrical wire [81].

Collector module needs to face south for case of photovoltaic, this depends on modular or central unit's modular.

- Module storage unit need maintenance
- The system need power inverter if the load requires AC current
- Highlight of relevant procedural differences from regular projects of this type will be needed
- Discuss requirements benefits and issues of using new procedures, and incorporating that into the total cost
- Procedure to build on will be described, hybrid system and integration system will be described and analyzed from the results and
- System successful complied with all regulations
- Efficiency penalty caused by extra power control equipment

Sola collector can be plate or dish type. Stefan` law relates the radiated power to temperature and types of surface:

$$\frac{P}{T} = \varepsilon \sigma T^4 \qquad (6)$$

Where P/A is the power in watts radiated per square meter, ε is surface emissivity, σ is Stefan Boltzmann constant= 5.67x10e8 W/ $m^2 . K^4$

The maximum intensity point of the spectrum of emitted radiation is given by:

$$\lambda_{\max} A = \frac{2898}{T(k)} \qquad (7)$$

Hybrid system: With a focus on developing applications for clean, renewable, non-fossil fuel, energy systems. Our final emphasis is on maritime related activities; however, as marine engineers we are devoted to promoting all types of alternative & sustainable energy technologies. Various types of engine, turbine and fuel cell may be run on a variety of fuels for combined heat and power production. Hybrid system can provide control over power needs, green and sustainable energy that delivers a price that is acceptable and competitive. The power plants can be located where it is needed less high power lines are required, not only reducing costs but assisting health by reducing magnetic fields that people are so worried about, Global warming is addressed by direct action by providing power that does not release any emissions or discharges of any kind. The technology associated with the design, manufacture and operation of marine equipment is changing rapidly. The traditional manner in which regulatory requirements for marine electrical power supply systems have developed, based largely on incidents and failures is no longer acceptable. Current international requirements for marine electrical power supply equipment and machinery such as engines, turbines and batteries have evolved over decades and their applicability to new technologies and operating regimes is now being questioned by organizations responsible for the regulation of safety and reliability of ships. Figure 79 and 80 shows hybrid configuration for conventional power, solar and hydrogen and Figure 81 shows physical model of hybrid of solar, wind and hydrogen being experimenting in UMT campus.

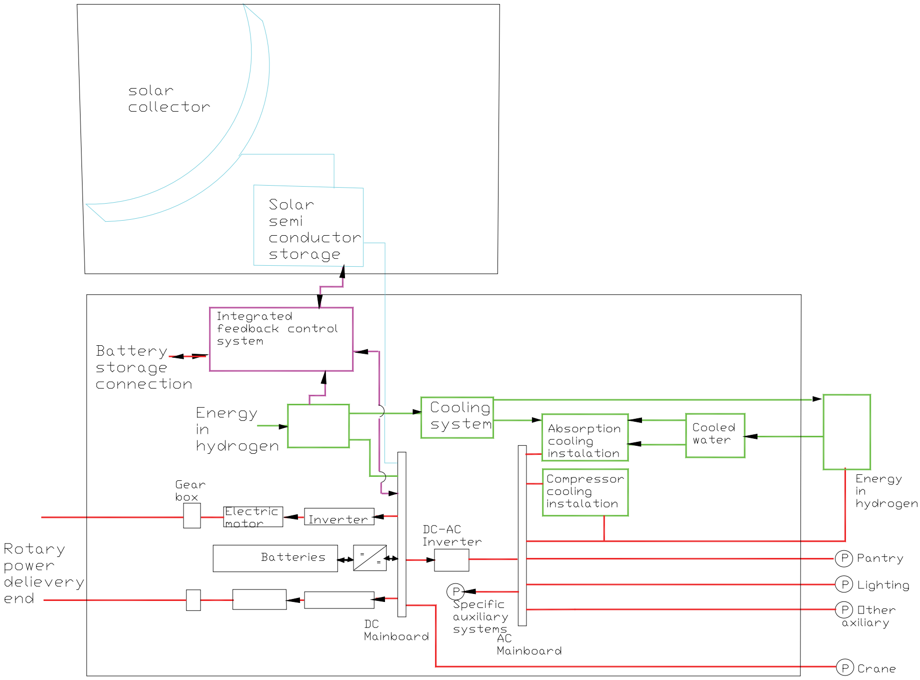


Figure 79: Hybrid configuration

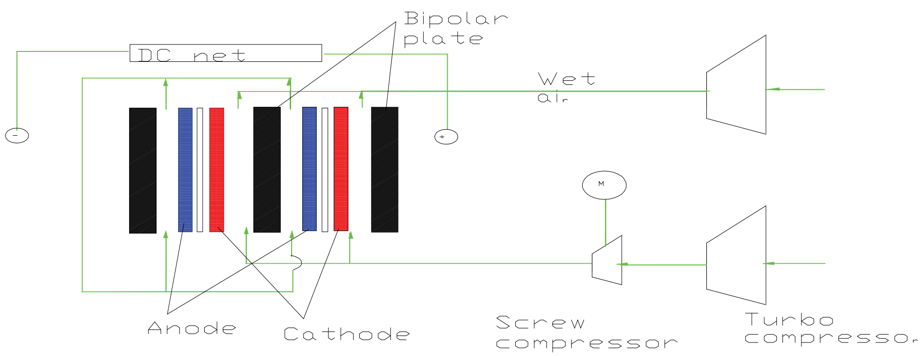


Figure 80: Hybrid configuration

Various technologies have been employed towards the use of alternative free energy of the sun since the first discovery in the 18th century. Improvement and development has been made towards making it available for use like existing reigning source of energy. Major equipment and hardware for the hybrid configuration are:

- Semi-conductor solar with high efficient storage capability will be designed
- Hybrid back up power will be design based with integrative capability to other alternative power source like wind and hydrogen
- Controller design for power synchronization will be designed and prototyped
- Inverter and other power conversion units will be selected based on power needs
- Solar collector or receiver with high efficiency collection capacity will be designed
- Software development and simulation
- Steam will be used as energy transfer medium

Figure 81: Physical model of hybrid system under experimentation in UMT.

The power plants can be built in small units combined, which allow greater control over the output and maintains full operational output 100% of the time. The plant produces fewer emissions, the plant can be located close to the areas where the power is required cutting down on the need for expensive high power lines. Excess energy produced can be connected to the grid under power purchase arrangement. The system can be built in independent power configuration and user will be free from supply cut out.

One of the unique features of hybrid system is the sustainable, clean energy system that uses a hydrogen storage system as opposed to traditional battery. Its design construction and functionality are inspired by the theme of regeneration and the philosophy of reuse. High efficiency solar panels works with an electrolyser to generate the hydrogen for fuel cell. The hybrid system can provide means to by-pass and overcome limitation posed by past work in generating replaceable natural energy of the sun and other renewable energy source that can be designed in hybrid system. Reliable deployment of hybrid system developments of mathematical model follow by prototyping, experimentation and simulation of the system are key to the design and its implementation. The main advantages of hybrid configurations are: Redundancy and modularity, high reliability of hybrid circuitry embedded control system, improve emergency energy switching and transfer, low operating cost through integrated design, low environmental impacts due to nature of the energy source [81-83].

Reliability and decision support framework: Various studies have been carried out to find the best hybrid supply for given areas. Results from specific studies cannot be easily applied to other situations due to area specific resources and energy use profiles and environmental differences. Energy supply system, with a large percentage of renewable resources varies with the size and type of area, climate, location, typical demand profiles and available renewable resource. A decision support framework is required in order to aid the design of future renewable energy supply systems, effectively manage transitional periods, and encourages and advance state of the art deployment as systems become more economically desirable. The DSS could involve the technical feasibility of possible renewable energy supply systems, economic and political issues. Reliability based DSS can facilitate possible supply scenarios to be quickly and easily tried, to see how well the demands for electricity, heat and transport for any given area can be matched with the outputs of a wide variety of possible generation methods. DSS can provide energy provision for port and help guide the transition towards higher percentage sustainable energy provision in larger areas. The hybrid configuration of how the total energy needs of an area may be met in a sustainable manner, the problems and benefits associated with these, and the ways in which they may be used together to form reliable and efficient energy supply systems. The applicability and relevance of the decision support framework can be shown through the use of a can simulate case study of the complex nature of sustainable energy supply system design.

Regulatory requirement and assessment: The Unifies International Association of Classification Society (IACS) unified requirements are applicable to marine power plant and electrical installations. A listing of the applicable requirements to marine power plants is shown in appendix of this paper. They IACS requirement provide prescriptive statements that provide a definition or identify what has to be done and in some cases how to do it. They relate to safety and reliability of marine power plant and support systems and arrangements. The current requirements have been developed based on reactive approach which leads to system failure. Reactive approach is not suitable for introduction of new technology of modern power generation systems. This call for alternative philosophy to the assessment of new power generation technologies together with associated equipment and systems from safety and reliability considerations, such system required analysis of system capability and regulatory capability [84,85]. System based approaches for regulatory assessment is detailed under goal based design as shown in figure.

IMO has embraced the use of goal based standards for ship construction and this process can be equally well applied to machinery power plants. Figure 82 illustrates the goal based regulatory framework for new ship construction that could be readily adapted for marine power plant application. Tiers of the goal base frame work are shown in Figure 83.

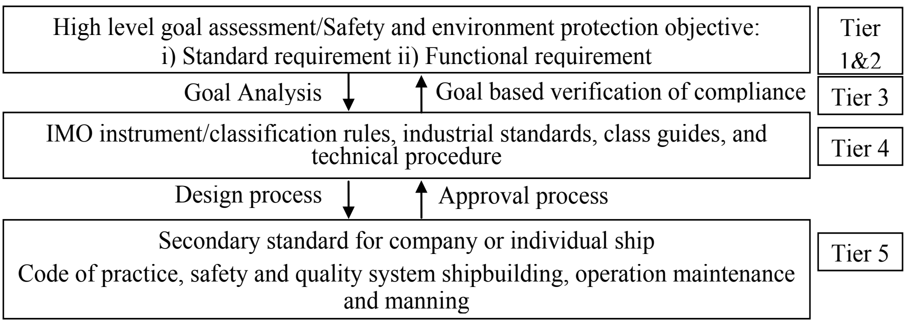


Figure 82: Components of level goal standard assessment.

Risk based design: The approach to risk assessment begins with risk analysis, a systematic process for answering the three questions posed at the beginning of this chapter: What can go wrong? How likely is it? What are the impacts? The analysis that describes and quantifies every scenario, the risk estimation of the triplets can be transformed into risk curve or risk matrix of frequency versus consequences.

Quantitative risk assessments: Analysis tools that now gaining general acceptance in the marine industry is Failure Mode and Effects Analysis (FMEA). The adoption of analysis tools requires a structure and the use of agreed standards. The use of analysis tools must also recognise lessons learnt from past incidents and experience and it is vital that the background to existing requirements stemming from SOLAS or IACS are understood. Consistent with the current assessment philosophy, there needs to be two tenets to the process safety and dependability. A safety analysis for a hybrid power generation system and its installation on board a ship could use a hazard assessment process such as outlined in Figure 83. The hazard assessment should review all stages of a systems life cycle from design to disposal.

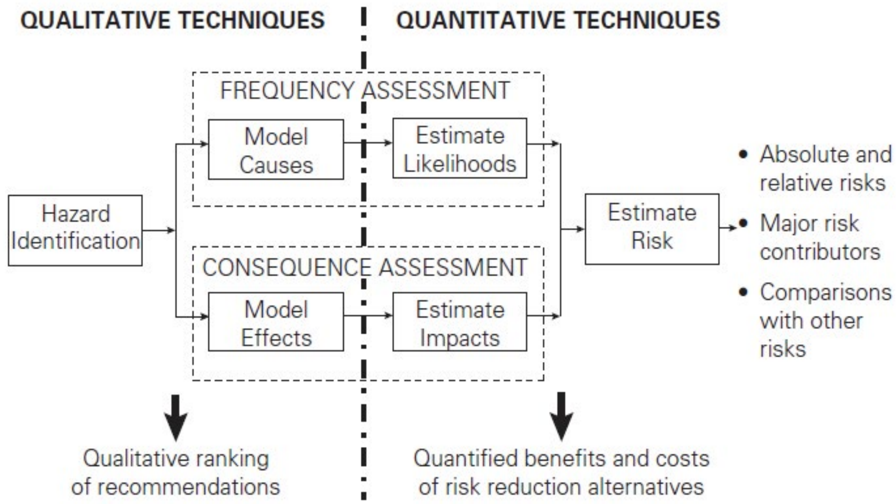


Figure 83: Components of risk and reliability analysis.

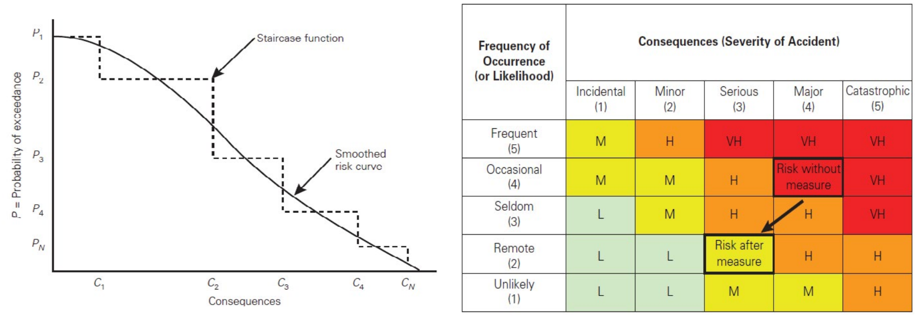
Figure 82 and 83 sows the components of risk assessment and analysis. The analysis leads to risk curve or risk profile. The risk curve is developed from the complete set of risk triplets. The triplets are presented in a list of scenarios rearranged in order of increasing consequences, that is, C1≤C2≤C3≤ ≤CN, with the corresponding probabilities as shown in Table 38. A fourth column is included showing the cumulative probability, Pi (uppercase P) as shown. When the points <Ci, Pi> are plotted, the result is the stair case function. The staircase function can be considered as discrete approximation of a nearly continuous reality. If a smooth curve is drawn through the staircase, that curve can be regarded as representing the actual risk, and it is the risk curve or risk profile that tells much about the reliability of the system. Combination of qualitative and quantitative analyses is advised to for risk estimates of complex and dynamic system.

Scenario	Probability	Consequence	Cumulative Probability
S1	P1	C1	P1=P1+P2
S2	P2	C2	P2=P3+P2
Si	Pi	Ci	Pi=Pi+3+Pi
Sn+1	Pn+1	Cn+1	Pn-1=Pn+Pn+1
Sn	Pn	Cn	Pn=Pn

Table 38: Components of risk and reliability analysis.

The design concept needs to address the marine environment in terms of those imposed on the power plant and those that are internally controlled. It is also necessary to address the effects of fire, flooding, equipment failure and the capability of personnel required to operate the system. In carrying out a hazard assessment it is vital that there are clearly defined objectives in terms of what is to be demonstrated. The assessment should address the consequence of a hazard and possible effect on the system, its subsystems, personnel and the environment. An assessment for reliability and availability of a hybrid power generation system and its installation in a ship could use a FMEA tool. An effective FMEA needs a structured approach with clearly defined objectives and IACS is currently developing standards that can uniformly be applied to marine systems and equipment where an analysis is required. The work currently being undertaken by IACS will identify those systems and machinery that require analysis. For a hazard and failure mode analysis it is necessary to use recognised standards and there are a number of generic standards that can be applied and adapted for analysis of a hybrid system Figure 84:

- IEC 61882, Hazard and Operability Studies (HAZOP) studies.
- IEC 60812, Analysis techniques for system reliability, application guide, Procedure for Failure Mode and Effects Analysis (FMEA).
- IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems.



a) b)

Figure 84: a) Stair case risk b) Risk priority matrix.

L = low risk, M = moderate risk, H = high risk; VH = very high risk.

The assessment analysis processes for safety and reliability need to identify defined objectives under system functionality and capability matching. These two issues are concerned with system performance rather than compliance with a prescriptive requirement in a standard. The importance of performance and integration of systems that are related to safety and reliability is now recognised and the assessment tools now available offer such means. Formal Safety Assessment (FSA) is recognised by the IMO as being an important part of a process for developing requirements for marine regulations. IMO has approved Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (MSC/Circ.1023/MEPC/ Circ.392). Further reliability and optimization can be done by using stochastic and simulation tools [14,15].

The development of requirements for fuel cells in the marine environment power plant application could usefully recognize the benefits of adopting a goal based approach. In order to determine the power supply capacity and system architectural arrangements required and to give specific requirements for services that affect the propulsion and safety of the vessel the various services are grouped under a number of headings.

Conclusion

Energy, environment, economic and efficiency and safety are the main technology driver today. Issue of energy and environment has been address. Problem associated with choice of energy system in the face of current environmental challenges has been discussed. The paper also discussed Standards and issues that are applicable to marine power generation systems. Alternative methods of assessment that can be applied to technology for which the current standards do not fit a recognized design and operating scenario and matter of lessons learnt from experience and from failures need to be understood before using alternative methods. Thus solar energy has been existing for a long time, different parties have done various research programs on to solar energy and hydrogen energy in different ways, a lot have been achieved in alternative energy technology. The state of the planet, surrounded with issue of energy pollutant shows current need for development of reliable production of alternative energy, since, previous work has shown lack of reliability on stand a lone system. Incorporating risk based DSS scheme for hybrid system that integrate conventional system with new system could bring a break through to counter problem associated with production of alternative energy. Previous regulatory work for system design has been prescriptive by nature. Performance based standards that make use of alternative methods of assessment for safety and reliability of component design, manufacture and testing is recommended for hybrid alternative energy system installation.

7. Risk and Reliability Analysis Study of Offshore Aquaculture Ocean Plantation System

Abstract

Complex system design is increasingly being based on risk and reliability analysis. Aquaculture is the fastest growing sector for seafood production and other bio-base technological processes. Considerable interest exists in developing open ocean aquaculture in response to a shortage of aquaculture product, suitable system, sheltered inshore locations and possible husbandry advantages of oceanic system. Concept of very large floating structure is adapted in aquaculture farming in ocean to produce more aquaculture product like seaweed. The risk analysis study of offshore aquaculture ocean plantation system is very important to determine the system functionality and capability that meet sustainable and reliability requirement. This paper describe process required to qualitatively assess system risk and quantify mooring failure probability, maximum force and required number of mooring as well as associated cost with the system.

Introduction

Since the early 1970s the technology, for very large floating structures has developed continually, while changing societal needs have resulted in many different applications of the technology for floating structure. Very large floating structure for offshore aquaculture of seaweed could be adapted offshore aquaculture ocean plantation system for oceanic farming of fish, prawn, squid and many more.

Seaweed encompass macroscopic, multicellular, polyphyletic, benthic marine algae that includes some members of the red, brown and green algae. Different type of seaweeds are available, they are classified by use for example as food, medicine, fertilizer, industrial, biomass and others. In addition, some tuft-forming blue green algae (Cyanobacteria) are sometimes considered as seaweeds. The usual type of seaweed that is used in ocean plantation is Cottonii seaweed or also known as Kappaphycus (*Eucheuma spp.*).

The design of very large floating structure for offshore aquaculture ocean plantation system required a reliable and risk free system with robust mathematical and simulation, risk and reliability of the hydroelastic structure, mooring system, structure, and material. Hence, the study of risk and reliability for the mooring system of offshore aquaculture ocean plantation system is required to make sure the system can function well, be monitored and accessed safety and efficiency. Typical mooring structure for offshore aquaculture include piers, docks, floats and buoys and their associated pilings, ramps, lifts and railways.

Generally, mooring structure is required to follow local and international requirements for offshore standards, materials, installation timing and surveys. The mooring structures should be able to withstand in critical saltwater and freshwater habitats when the standards, overwater structures shall be constructed to the minimum size necessary to meet the needs of ocean resources exploration use.

Mooring system for VLFS need risk and reliability analysis of the associated criticality. Risk analysis of offshore aquaculture ocean plantation system focus on analyzing mooring structure with hope to help determine safe, reliability and efficiency of the system. Qualitative assessment and quantitative risk assessment analysis methods are explored towards reliable decision support for VLFS. Qualitative assessment analysis employed qualitative tools like checklist, and HAZOP (Hazard and Operability Study) that define the system while quantitative risk analysis, the methods employed include Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Risk Control Option based on HAZID (Hazard Identification) process. The risk of disaster cannot be eliminated but risk can be reduced by employing better safety detection technique and establishing safety criteria prior to an accident occurrence.

This paper describe development of simplified but holistic methodology that determine risk based decision support for reliable design and development of VLFS system, the risk analysis focus on mooring structure failure and reliability through employment of risk tools like FMEA, FTA, RCO and HAZID.

Background

The seaweed extract, (Carrageenan) is an important hydrocolloids product for food additive ingredient and it is highly demanded in the world market. Seaweed is also used for biomass energy production as well as pharmaceutical and medicinal product. The demand for seaweed has created huge market for this raw material, especially, the Cottonii seaweed also known as Kappaphycus (*Euchema spp.).* For exemple, under the Malaysian Government NKEA, there is need to produce 1 million tonnes seaweed every year. Unfortunately, currently there is no proper system or plat form to deliver this demand.

The mooring system failure analysis is very important part in the development offshore aquaculture ocean plantation systems; risk analysis is required to determine the system function duty and performance. Besides that, there will be increasing demand for concept of floating technology worldwide, so the concept of offshore aquaculture ocean plantation system can be applied for the technology platform required. There is currently no systematic and formal proactive methodology for offshore aquaculture floating structure design. Offshore floating structure is required to be reliable in order to withstand harsh environment. A risk and reliability studies of offshore aquaculture system for mooring structure will contribute to sustainable development of the seaweed farming industry as well as improvement of technology platform for other aquaculture farming in open seas.

The study involves conduct and determination the reliability analysis that can reduce the probability of accident risk occurrence and impact in offshore aquaculture system for ocean plantation. Especially mooring structure system integrity and reduction of consequence of failure. The studies access the risk, system functionality and capability of offshore aquaculture seaweed plantation for mooring structure. The study also estimate the risk in design of mooring structure for deployment of very large floating structure for oceanic aquaculture seaweed plantation and ddecision recommendation will be offered for level integrity of oceanic aquaculture seaweed plantation for mooring structure.

Significant/rationale of risk based design VLFS: The study VLFS, fall under complex and new system, unlike system like ship, offshore structure, that have of the shelf guideline, new method is required for design and development of reliable VLFS for aquaculture seaweed farming. The risk and reliability analysis is one best approach to use for offshore aquaculture ocean plantation system of mooring system and VLF structure that withstands the aspects that has been tested in the system design and development. The risk approch investigate more detailed the risk, specification and requirement that the system needs to make sure that it is reliability for deployment of capability. The significant of this using risk method for VLFS are:

- To avoid system failure according recommendation from quantifying and dedution of improvement measures
- Identify inadequate mooring strength due to poor material quality of fatigue in order to determine required mitigation.
- Identified excessive environmental forces for example under estimated or freak environmental condition and determine solution for system additional uncertainty.
- Predicted incorrectly mooring tension based on the reviews and analysis of the system.
- Perfomed risk and reliability leads to recommend the best safety level integrity of oceanic aquaculture seaweed plantation for mooring structure to alert the risk and improve reliability of this system.

Case study area: The risk analysis condsiders east coast, Malaysia. The area identified and applied in Terengganu is the water body of water that is know for harsh weather, thus inheritably buffer area that provide and right way for sea traffic and water depth is prevalent location consideration of for seaweed farming. Other location ideal for seaweed cultivation are areas with absence of larger feeder river systems in its vicinity and reasonable deep waters that will ensure stability in its salinity and some degree of shelter protected by the chain of island off coast of the area. Such location required to fulfils the prime factors for seaweed culture which are suitable water condition and good exchange of seawater. Both these two factors can be found in the State of Terengganu especially in the coastal area off Setiu. Besides these two factors, the relatively developed infrastructure and logistic network in Terengganu are also some of the important supporting factors for this system development.

Data requirement: The study data are collected from specific source and method. The right source of data should be chosen to make sure the data are true and valid for this study analysis. The data are also obtained from model test, Meteorology Department, JPS (Jabatan Pengaliran dan Saliran), Offshore Company and Aquaculture Company.

VLFS: Very Large Floating Structures (VLFSs) or Very Large Floating Platforms (VLPs) can be constructed to create floating airports, bridges, breakwaters, piers and docks, storage facilities (for oil and natural gas), wind and solar power plants, for military purposes, to create industrial space, emergency bases, entertainment facilities such as casinos, recreation parks, mobile offshore structures and even for habitation. VLFS for habitation could become reality sooner than one may expect. Currently, different concepts have been proposed for building floating cities or huge living complexes. The system is constituted by vertical tethers. This characteristic makes the structure very rigid in the vertical direction and very flexible in the horizontal plane. Both these features results particularly attractive. The vertical rigidity helps tie in wells for production, while, the horizontal compliance makes the platform intensive primary effect of waves [86].

Pontoon type VLFS are mat-like VLFSs because of their small draft in relation to the length dimensions. Very large pontoon type floating structure is often called Mega Floats. As a rule, Mega Floats is floating having at least one length dimension greater than 60 meters. Horizontally large floating structures can be from 500 to 5000 meters in length and 100 to 1000 meters in width, while their thickness can be of the order of about 2-10 meters.

Analysis and design of very large floating structures: Clauss state that in year 1992, the analysis and design of floating structures need to account for some special characteristics. That statement is valid when comparing to land based structures. In a floating structure, the static vertical self weight and pay loads are carried by buoyancy. If a floating structure has got a compliant mooring system, consisting for instance of catenaries chain mooring lines, the horizontal wave forces are balanced by inertia forces. That shows that if the horizontal size of the structure is larger than the wavelength, the resultant horizontal forces will be reduced due to the fact that wave forces on different structural parts will have different phase which is direction and size.

The forces in the mooring system will then be small relative to the total wave forces. The main purpose of the mooring system is then to prevent drift-off due to steady current and wind forces as well as possible steady and slow drift wave forces which are usually more than an order of magnitude less than the first order wave forces. Sizing of the floating structure and its mooring system depends on its function and also on the environmental conditions in terms of waves, current and wind [87]. The design may be dominated either by peak loading due to permanent and variable loads or by fatigue strength due to cyclic wave loading. Moreover, it is important to consider possible accidental events and ensure that the overall safety is not threatened by a possible progressive failure induced by such damage.

Clauss explain that, unlike land-based constructions with their associated foundations poured in place, very large floating structures are usually constructed at shore based building sites remote from the deep water installation area and without extensive preparation of the foundation. Each module must be capable of floating so that they can be floated to the site and assembled in the sea. Owing to the corrosive sea environment, floating structures have to be provided with a good corrosion protection system and also possible degradation due to corrosion or crack growth (fatigue) requires a proper system for inspection, monitoring, maintenance and repair during use.

Design considerations for mooring structure: The mooring system must be well designed to ensure that the very large floating structure is kept in position so that the facilities installed on the floating structure can be reliably operated and to prevent the structure from drifting away under critical sea conditions and storms [88]. There are a number of mooring systems such as the dolphin-guide, frame system, mooring by cable and chain, tension leg method and pier/quay wall method.

The design procedure for a mooring system may take the following steps. First select the mooring method, the shock absorbing material, the quantity and layout of devices to meet the environmental conditions and the operating conditions and requirements. The layout of the mooring dolphins for example is such that the horizontal displacement of the floating structure is adequately controlled and the mooring forces are appropriately distributed.

In role of reliability analysis, the behavior of the floating structure under various loading conditions is examined. The layout and quantity of the devices are adjusted so that the displacement of floating structure and the mooring forces do not exceed the allowable values. Finally, the floating structure is designed by applying the design load based on the calculated mooring forces. The materials for the mooring system shall be selected according to the purpose, environment, durability and economy.

According to C.W.Lee, the deformation of the mooring line for floating structures can happen due to current act. The shapes of the structures change to a considerable degree by the water flow and the large tension working on the mooring line of the upper side. The degree of deformation of the structures and the tension of the mooring line depend on the size of flow speed and materials. The tension of the mooring line on the upper side of the tide and waves changes regularly and become higher by a maximum of 250% than when only tides works on it.

The seaweed industry

Seaweed farming: Harvesting seaweed from wild population is an ancient practices dating back to the fourth and sixth centuries in Japan and China, respectively, but it was not until the mid-twentieth century that methods for major seaweed cultivation were developed. Since that time, seaweed farming or marine agronomy has grown rapidly due to demand that has outpaced the productivity of natural populations. Today almost 90% of seaweed for human use comes from cultivation, rather than wild harvests (Zemke-White & Ohno).

Seaweed has traditionally been grown in nearshore coastal waters, with some smaller operations on land. Offshore systems which is the focus of this study are an emerging seaweed culture technology. The key components of the Chinese seaweed farming industry (Chen) and type of Cottonii seaweed or also known as Kappaphycus *(Eucheuma spp.).*

Seaweed growth of life cycle: Seaweed life cycles are complex in many species, with annual and perennial species and sexual and asexual reproductive modes, resulting in isomorphic or heteromorphic life history forms, commonly referred to as alternation of generations. Understanding the complex and diverse life cycles of different seaweeds is of practical significance in controlling growth and reproduction for optimal plant husbandry. An example in which our increased understanding of life cycle had clear economic impact was the identification of the conchocelis, originally considered a separate organism, as a one of the diploid stages of Porphyra spp. This recovery revolutionized the culture of commercially cultivated seaweed in Japan, China, and Korea. The conchocelis become the seed stock source for artificial propagation of this seaweed.

The seaweed industry: The global production of all aquaculture products in 2004 was 59.4 million metric ton with a total value of $70.3 billion. Of this almost a quarter by weight but only a tenth by value ($6.8 billion) was aquatic plants, 99.8% of which were farmed in Asia and the Pacific Region. Seaweed farms worldwide are estimated to produce 13.9 million metric ton wet weight per year.

Seaweed farming has become an economically important natural resource for Malaysia since 1978, when it was first introduced to Semporna, east coast of Sabah on a commercial scale. It has develop the aquaculture activities in Sabah as a second largest contributor from marine aquaculture which produce 60% from total value of exported fisheries product at MR$114 million (1994-1997) [89]. It has wide application potentials similar to other commodities such as palm oil and cocoa. This has been approved during the Ninth Malaysia Plan (2006-2010) and the Third National Policy (1998-2010) with seaweed being mentioned specifically as one of the most important aquaculture product of food farming commodities for the country. Although the sector of seaweed industry has developed enormously over the past few years (111,298 tonnes wet weight in 2008), seaweed production and national target on 2010 of 250,000 tonnes (wet weight) is however yet to be achieved [90].

In the Tenth Malaysia Plan, the government estimates to produce 1 million tonnes of seaweed by 2015. Consequence from this target, there are many efforts to bring the industry of seaweed farming to the Peninsular Malaysia specifically in the east coast area which offers high potential to be developed as commercial area for seaweed farming. In contrast, east coast of peninsular Malaysia is the area that is exposed directly to the strong sea currents and periodic monsoon season which is prevalent off the east coast. Furthermore, with the nature elements of the deep and open water environment, seaweed farming is hard to be applied in this area. However, Marine System Engineering can deliver system that could solve this problem.

Risk analysis: Risk analysis are best used for assessing and evaluating uncertainties associated with an event, risk is defined as the potential for loss as a result of a system failure and can be measured as a pair of factors, one being the probability of occurrences of an event, also called a failure scenario, and the other being the potential outcome or consequence associated with the event's occurrence [91].

A risk assessment is the process used to determine the risk based on the likelihood and impact of an event. Failure history through experience (qualitative) and data (quantitative) may be used to perform a risk assessment.

Risk analysis is concerned with using available data to determine risk posed by safety hazards and usually consists of steps such as scope definition, hazard identification and risk determination. The phase in which the decision process is in undated with metrics and judgments is called the risk evaluation. The purpose of analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendation, if any, with the aim of preventing similar accidents occurring again.

There are many sources of risk to marine systems including human error, external events, equipment failure and installation error [91]. Risk is defined as the product of likelihood of occurrence and consequences of an accident. Risk analysis or assessment helps to answer basically three questions as shown in Figure 85.

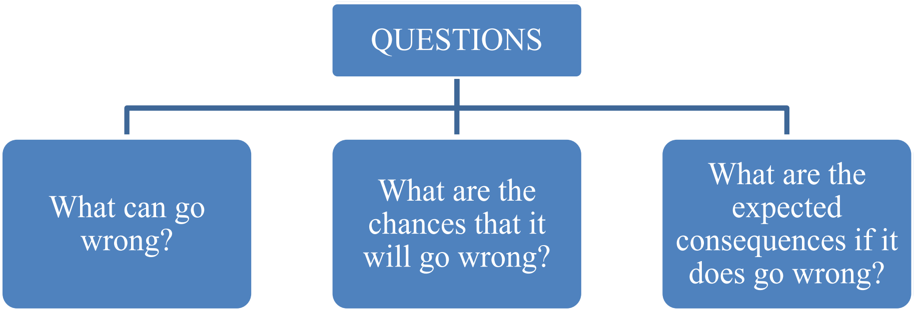


Figure 85: Questions Answered by Risk Assessment or Analysis.

Qualitative analysis relies on statistical methods and data bases that identify the probability and consequence. This objective approach examines the system in greater detail for risk. Quantitative risk analysis generally provides a more uniform understanding among different individuals but requires quality data for accurate results. Qualitative risk analysis uses expert opinion to evaluate the probability and consequence. This subjective approach may be sufficient to access the risk of a marine system. The qualitative method for risk assessment or analysis is designed for the purpose of enhancing one's awareness of potential problems and can assist one in analyzing the risks. A combination of both qualitative and quantitative risk analysis can be used depending on the situation. There are many methods and technique that have been developed to perform various types of analysis, in areas such as reliability and safety. In order to perform risk assessment and analysis method, this can be determined by quantitative and qualitative risk analysis tools presented in Table 39 below:

Quantitative Methods
Failure Modes and Effects Analysis (FMEA) Identifies the components (equipment) failure modes and the impact on the surrounding components and the system.
Fault Tree Analysis (FTA) Identify combinations of equipment failure and human errors that can result in an accident.
Event Tree Analysis (ETA) Identify various consequences of events, both failures and successes that can lead to an accident.
Qualitative Methods
ALARP Possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.
Checklist Ensures that organizations are complying with standard practice.
Safety/Review Audit Identify equipment conditions or operating procedures that could lead to a casualty or result in property damage or environment impacts.
What-If Identify hazards, hazardous situations, or specific accident events that could lead to undesirable consequences.
Hazard and Operability Study (HAZOP) Identify system deviations and their causes that can lead to undesirable consequences and determine recommended actions to reduce the frequency and/or consequences of the deviations.

Preliminary Hazard Analysis (PrHA) Identify and prioritize hazards leading to undesirable consequences early in the life of a system. Determine recommended actions to reduce the frequency and/or consequences of prioritized hazards.

Table 39: Quantitative and qualitative risk analysis.

FMEA: Failure Modes and Effects Analysis (FMEA) is a powerful tool used by the system safety and reliability engineers/analysts to identify critical parts functions and components whose failure will lead to undesirable outcome such as production loss, injury or even an accidents. The tool was first proposed by NASA in year 1963 for their obvious reliability requirements. Since then, it has been extensively used as a powerful technique for safety and reliability analysis of products and process in wide range of industries that are particularly aerospace, nuclear, automotive and medical.

Failure Modes and Effects Analysis (FMEA) is a method to analyze potential reliability problems in the development cycle of the project, making it easier to take actions to overcome such issues, enhancing the reliability through design. FMEA is used to determine actions to mitigate the analyzed potential failure modes and their effect on the operations. Expected failure modes, being the central step in the analysis, needs to be carried on extensively, in order to prepare a list of the maximum potential failure modes.FMEA is also a procedure for evaluating the various aspects of a system in order to identify all catastrophic and critical failure possibilities so that they can be eliminated or minimized through design correction at the earliest possible time (MIL-STD-1629A, 1980).

FTA: Fault Tree Analysis (FTA) is a tool for analyzing, visually displaying and evaluating failure paths in a system, thereby providing mechanism for effective system level risk evaluation. Many people and corporation are already familiar with this tool and use it on a regular basis for safety and reliability evaluations, FTA has become an important tool in system design and development and history related to the basic should be recorded and appropriate people duty recognized. FTA is based on Reliability theory, Boolean algebra and probability theory.

Reliability analysis: Reliability analysis methods have been proposed in several studies as the primary tool to handle various categories of risks Billinton, Janjic and Popovic. Traditionally, the research and the development of reliability analysis methods have focused on generation and transmission. However, several studies have shown that most of the customer outrages depend on failures at the distribution level (Billinton and Allan; Billinton and Sankarakrishnan; Bertling). Furthermore, there is an international tendency towards adopt new performance based tariff regulation methods Billinton & Mielczarski.

Hence, reliability of a system can be defined as the system's ability to fulfil its design functions for a specified time. This ability is commonly measured using probabilities. Reliability is, represent the probability that the complementary event that will occur will leads to failure. Based on this definition, reliability is one of the components of risk. Safety can be defined as the judgment of a risk's acceptability for the system safety, making it a component of risk management [91].

Risk analysis in maritime industry: International Maritime Organization state that, Formal Safety Assessment (FSA) is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property by using risk analysis and cost benefit assessment. FSA can be used as a tool to help in the evaluation of new regulations for maritime safety and protection of the marine environment or in making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and benefit between maritime safety or protection of the marine environment and costs.

FSA consists of five steps which are, firstly is identification of hazards that means a list of all relevant accident scenarios with potential causes and outcomes, secondly is assessment of risks means that the evaluation of risk factors, thirdly is risk control options that is devising regulatory measures to control and reduce the identified risks, fourthly is cost benefit assessment which determining cost effectiveness of each risk control option and lastly recommendations for decision making conclusion from the information about the hazards, their associated risks and the cost effectiveness of alternative risk control options.

The ALARP principle: ALARP (As Low as Reasonably Practicable) is a used in the analysis of safety critical and high-integrity systems. The ALARP principle define residual risk that shall be as low as reasonably practicable, it has been used for decision support for Nuclear Safety Justification, is derived from legal requirements in the UK's Health & Safety at Work Act 1974 and is explicitly defined in the Ionising Radiation Regulations, 1999. The ALARP principle is part of a safety culture philosophy and means that a risk is low enough that attempting to make it lower would actually be more costly than cost lkely to come from the risk itself. This is called a tolerable risk. The ALARP principle arises from the fact that it would be possible to spend infinite time, effort and money attempting to reduce a risk to zero. It should not be understood as simply a quantities measure of benefit against detriment. It is more a best common practice of judgement of the balance of a risk and societal benefits.

The meaning and value of the ALARP tolerability risk presented in Figure 86 the triangle represents increasing levels of risk for a particular hazardous activity, as we move from the bottom of the triangle towards the top.

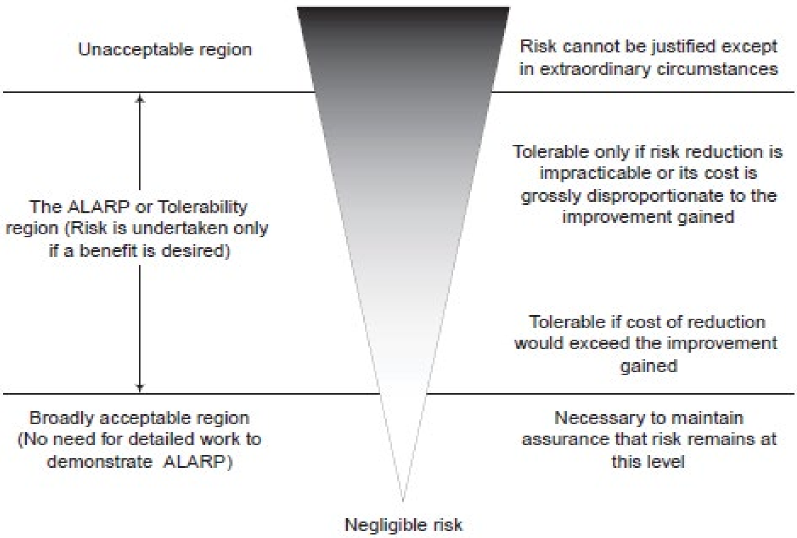


Figure 86: Levels of Risk and As Low As Is Reasonably Practicable (ALARP).

Offshore industry risk analysis: Traditionally, offshore Quantitative Risk Analyses (QRAs) have had a rather crude analysis of barrier performance, emphasizing technical aspects related to consequence reducing systems.However, recently the Petroleum Safety Authority Norway (PSA) has been focusing on safety barriers and their performance both in regulations concerning health, safety and environment (PSA) and in their supervisory activities.

The development of offshore Quantitative Risk Assessment (QRA) has been lead by the mutual influence and interaction between the regulatory authorities for the UK and

Norwegian waters as well as the oil companies operating in the work sea. Also, other countries have participated in this development but to some extent this has often been based on the British and Norwegian initiatives according to DNV Consulting Support, GI 291, Det Norske Veitas AS, 1322 Hovik, Norway.

In more recent times, efforts to protect citizens and natural resources, has make governments to be more involved, requiring corporations to employ risk-reducing measures, secure certain types of insurance and even, in some cases, demonstrate that they can operate with an acceptable level of risk. During the 1980's and 1990's more and more governmental agencies have required industry to apply risk assessment techniques. For instance, the U.S. Environmental Protection Agency requires new facilities to describe worst case and expected environmental release scenarios as part of the permitting process. Also, the United Kingdom requires submittal of Safety Cases which are intended to demonstrate the level of risk associated with each offshore oil and gas production facility (ABS Guidance Notes on Risk Assessment, 2000)

Offshore rule for offshore structure: The variety of offshore structures concerning the function, size, geometrical configuration and material selection as well as the variability of the environmental factors complicate the development of a unique design procedure (Research Centre Asia Classification Society, 2003). Therefore, the separate investigation of the interaction between the actual structure and the environment is necessary.

For mooring system offshore rules use reference documents NI 493 Classfication of Mooring System for Permanent Offshore Units. The design and specification of mooring structure for offshore aquaculture ocean plantation system must be based on all requirements had listed and mention in NI 493 document.

Safety and risk of offshore aquaculture: The EC-JRC International Workshop on Promotion of Technical Harmonization on Risk-Based Decision Making (Stresa/Ispra, May 2000) investigated the use of risk-based decision making across different industries and countries. Under the UK safety case regulations (UK Health and Safety Executive, 1992) each operator in the UK Sector is required to prepare a Safety Case for each of its installations, fixed or mobile, to demonstrate that:

- The management system adequately covers all statutory requirements.
- There are proper arrangements for independent audit of the system.
- The risks of major accidents have been identified and assessed.
- Measures to reduce risks to people to the lowest level reasonably practicable have been taken.
- Proper systems for emergency arrangements on evacuation, escape and rescue are in place.

Before an installation is allowed to operate, the Safety Case must be formally accepted by the Health and Safety Executive (HSE). Like any aquaculture industry, offshore aquaculture will benefit from thoughtful site selection. Offshore enterprises should be sited in areas that meet optimal biological criteria for species grow-out and minimize user conflicts with other established groups. Careful site selection may also ensure the development of offshore aquaculture zones or parks to expedite industry development.

Failure of mooring system: It is clearly identified that mooring systems on Floating Production Systems are category 1 safety critical systems (Noble Denton Europe Limited). Multiple mooring line failure is required to put lives at risk both on the drifting unit and on surrounding installations. There is also a potential pollution risk. Research to date indicates that there is an imbalance between the critical nature of mooring systems and the attention which they receive.

The mooring system failure probability is considerably reduced with increases safety factor in particular for system with several parallel loads sharing element. For system with low overall safety factor, the mooring system failure probability is expected to increase with increasing in number of lines, whereas for high safety factors, the system failure probability is expected to reduce with the increasing number of lines. While for the same load distribution and number of lines, a wire system is in general more reliable than a chain system with the same overall safety factor.

Material and methods: General idea of the risk and reliability analysis study of offshore aquaculture ocean plantation system focus on mooring structure of offshore aquaculture systemas well as investigation of the problem, goal and objectives, adavantage, disadvantage, limitation, desighnn for environment, data reliabiliuty. Analysis of historical information from various sources play mportant role in the outcome of system identification.Flow chart and tables and mathematical governing equation are used to present detail of the process and procedure. The outcome of risk leads to recommendation for system reliability of future work. This study process followed three tiers, preliminary system identification, qualitative risk assessment that involves HAZID process and quantitative risk. The process of the approach is more elaborated as followed.

Preliminary system assessment and involve the review of past work data collection and general requirement for mooring structure. Data of analyses of offshore aquaculture ocean plantation mooring system and structure are collected in order to define system, deduce system risk areas and reliability areas.

(HAZID) Hazard Identification qualitative process involves clarification risk. For risk analysis had two processes which are qualitative analysis and quantitative analysis. Qualitative assessment use HAZOP and checklist, Fault Modes and Effect Analysis (FMEA), Fault Tree Analysis (FTA).

Quantitative analysis involves Analytical process that employed hybrid of deterministic, statistical, reliability and probabilistic method to redefine system behavior in the past, present and future. These use of law physics, help to strength the analysis and support the study of the risk and reliability of this system.

In result of each of the tier can lead to risk matrix, ALARP graph Risk Control Option (RCO) and cost Effectiveness Analysis.

Since the design of VLFS for seaweed farming is required new methodology based on risk, guideline systems for solving a problem with specific components such as phases, tasks, methods, technique and tools that are incoroporated are (Irny, S.I. and Rose, A.A, 2005). It can define as follows:

- The analysis of the principles of method, rules and postulates employed by a discipline.
- The systematic study of methods that are, can be or have been applied within a discipline.
- The study of description of methods.

The methodology for this study is shown below in Figure 87.

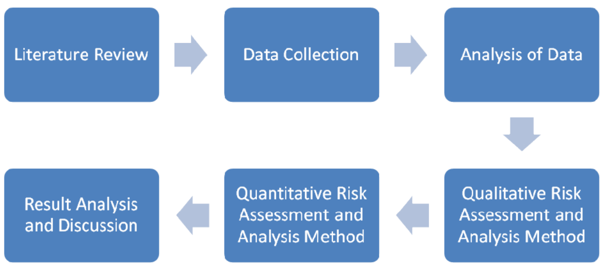


Figure 87: Flow Chart for Research Methodology.

Safety and Environmental Risk Model (SERM): SERM methology adapted from O.O.Sulaiman [92] intend to address risk over the entire life of the complex system. SERM address qualitative aspect as well quantitatively accidents frequency and consequences VLFS, as shown in Figure 87.

Data: The raw collection data is obtained from specific places and method. The right sources should be chosen to make sure the data is reliable and valid for the study analysis. Some of the data will be obtained from model test, Meteorology Department, JPS (Jabatan Pengaliran dan Saliran), Offshore Company, Aquaculture Company and last but not least Seaweed Block System SBS Project in Setiu, Terengganu and Sabah.

Data analysis: The raw collection data is obtained from specific places and method. The right sources should be chosen to make sure the data is reliable and valid for the study analysis. Some of the data will be obtained from model test, Meteorology Department, JPS (Jabatan Pengaliran dan Saliran), Offshore Company, Aquaculture Company and last but not least Seaweed Block System SBS Project in Setiu, Terengganu and Sabah.

- Qualitative risk assessment and analysis method
- System Defination
- Qualitative Assessment
- Tools emlloyed for qualitative assessment are describe below:
- Checklist

This is qualitative approach to insure the organization is complying with standard practice. The checklist can be used as a preparation for system design, deployment, maintenance and monitoring to avoid unnecessary problems and delays. The checklist included in the International Safety Management (ISM) procedures as documentation about checks for maintenance can be adopted for this study. The list can be filled in manually or printout electronically.

Checklist analysis is a systematic evaluation against pre-established criteria in the form of one or more checklists. It is applicable for high-level or detailed-level analysis and is used primarily to provide structure for interviews, documentation reviews and field inspections of the system being analyzed. The technique generates qualitative lists of conformance and non-conformance determinations with recommendations for correcting non-conformances. Checklist analysis is frequently used as a supplement to or integral part of another method especially what-if analysis to address specific requirements. The quality of evaluation is determined primarily by the experience of people creating the checklists and the training of the checklist users. The checklist analysis used most often to guide inspection of critical systems. It is also used as a supplement to or integrates part of another method, especially what-if analysis to address specific requirements.

Procedures for Checklist Analysis,

- Define the activity or system of interest
- Define the problems of interest for the analysis
- Subdivide the activity or system for analysis
- Create relevant checklists
- Respond to the checklist questions
- Further subdivide the elements of the activity or system (if necessary or otherwise useful)
- Use the results in decision making

Hazard and Operability Study (HAZOP): A hazard and Operability (HAZOP) study is a qualitative risk analysis technique that is used to identify weaknesses and hazards in a processing facility or system; it is normally used in the planning phase (design). The HAZOP technique was originally developed for chemical processing facilities, but it can also be used for other facilities and systems. For example, it is widely used in Norway in the oil and gas industry.

A HAZOP study is a systematic analysis of how deviation from the design specifications in a system can arise and an analysis of the risk potential of these deviations.Based on a set of guidewords, scenarios that may result in a hazard or an operational problem are identified. The following guidewords are commonly used: no/not, more of/less of as well as, part of reverse and other than. The guidewords are related to process conditions, activities, materials, time and place. The question would be Figure 88:

- What must happen to ensure the occurrence of the deviation no throughput (cause)?
- Is such an event possible (relevance/probability)?
- What are the consequences of no throughput (consequence)?

As a support in the work of formulating meaningful questions based on the guidewords, special forms have been developed. The principle that is used in a HAZOP study can be illustrated in the following way:

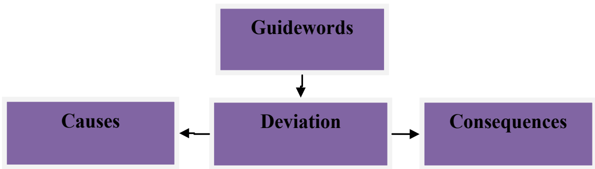


Figure 88: HAZOP study is a systematic analysis.

In HAZOP study, critical aspects of the design can be identified, which requires further analysis. Detailed, quantitative reliability and risk analyses will often be generated after that. A HAZOP study of a planned plant or system will, in the same way as an FMEA, normally be most useful if the analysis is undertaken after the System Operation and Monitoring have been worked out. It is at this point in time that sufficient information about the way the plant is to be operated is available. A HAZOP study is a time and resource demanding method. Nevertheless, the method has been widely used in connection with the review of the design of process system for a safer, more effective and reliable system.

Quantitative risk assessment and analysis method

Hazard identification: Hazard identification (HAZID) and risk assessment involves a critical sequence of information gathering and the application of a decision-making process. These assist in discovering what could possibly cause a major accident (hazard identification), how likely it is that a major accident would occur and the potential consequences (risk assessment) and what options there are for preventing and mitigating a major accident (control measures). These activities should also assist in improving operations and productivity and reduce the occurrence of incidents and near misses. The flowchart below summarises all the steps needed in a HAZID process.

Major accidents by their nature are rare events, which may be beyond the experience of many employers. These accidents tend to be low frequency, high consequence events as illustrated in Figure 1 below. However, the circumstances or conditions that could lead to a major accident may already be present, and the risks of such incidents should be proactively identified and managed. Figure 89 shows the HAZID flowchart for typical rare events.

In assessing safety systems, towards deduction of option to mitigate the effects of external hazards, the assessor should have due regard to Reliability, redundancy, diversity and segregation.External hazards may particularly give rise to common mode or common cause failures.

Failure Modes and Effect Analysis (FMEA): A Failure Modes and Effects Analysis (FMEA) is a procedure in product development and operations management for analysis of potential failure modes within a system for classification risk i2by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. Failure modes are any errors or defects in a process, design or item, especially those that affect the intended function of the product and or process and can be potential or actual. Effects analysis refers to studying the consequences of those failures. The Figure 89 and 90 below shows FMEA process toward determining the Risk Priority Number (RPN).

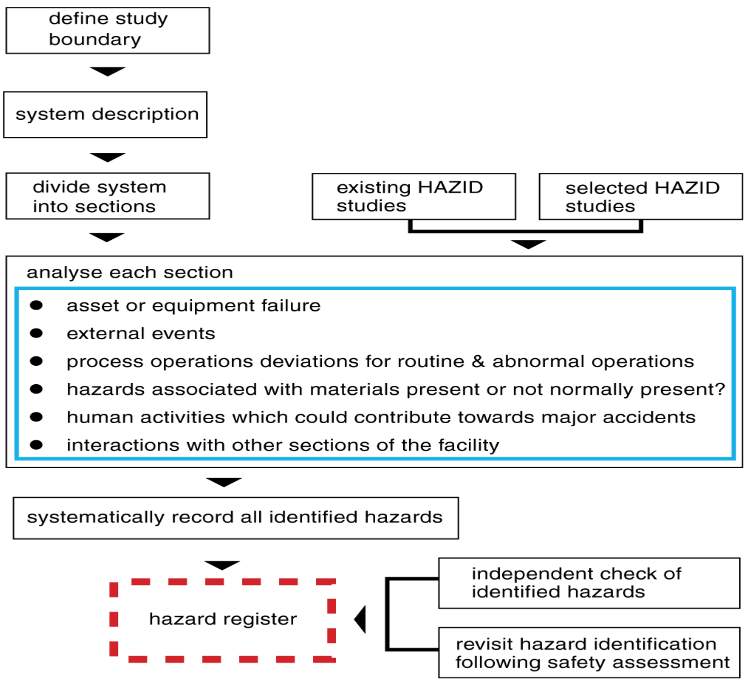


Figure 89: HAZID rare events process and HAZID events process.

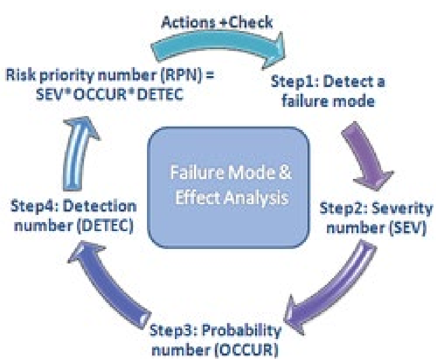


Figure 90: Risk1 Priority Number.

The RPN (Risk Priority Number) is the product of Severity, Occurrence and Detection (RPN = S x O x D) and is often used to determine the relative risk of a FMEA line item. In the past, RPN has been used to determine when to take action.RPN should not be used this way. RPN is a technique for analyzing the risk associated with potential problems identified during a Failure Mode and Effects Analysis. RPN=Severity Rating x Occurrences Rating x Detection Rating, is the formula used in FMEA. FMEA procedures are:

Define the system and its performance requirements:

- State all assumptions and ground rules that will be used in the analysis.
- Develop block diagrams of the system and identify possible failure modes for example breaking, cracking, snap weather and others.
- Identify cause of each failure mode.
- Determine impact of every possible failure mode on the operation of affected items, items of subsequent assemblies, and the total system.
- List the possible symptoms of all failures and the means used to detect the failure.
- Assign a severity ranking to each failure mode.
- Assign an occurrence ranking to each failure mode for example estimate of the probability of the failure based on actual event occurence.
- For each potential failure mode, perform a criticality analysis.
- Evaluate and recommend any corrective actions and improvements to the design.

Fault Tree Analysis (FTA): Fault tree analysis (FTA) is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the field of safety engineering and Reliability engineering to determine the probability of a safety or accident or a particular system level (functional) failure.

In Aerospace the more general term system. Failure Condition is used for the undesired state v Top event of the fault tree. These conditions are classified by the severity of their effects. The most severe conditions require the most extensive fault tree analysis. These system Failure Conditions and their classification are often previously determined in the functional Hazard analysis. FTA can be used to:

Understand the logic leading to the top event/undesired state.

Show compliance with the (input) system safety/reliability requirements.

Prioritize the contributors leading to the top event-Creating the Critical Equipment/ Parts/Events lists for different importance measures.

Monitor and control the safety performance of the complex system (e.g. is it still safe to fly an Aircraft if fuel valve x is not working? For how long is it allowed to fly with this valve stuck closed?).

Minimize and optimize resources. Assist in designing a system. The FTA can be used as a design tool that helps to create (output/lower level) requirements.

Function as a diagnostic tool to identify and correct causes of the top event. It can help with the creation of diagnostic manuals/processes.

Many different approaches can be used to model a FTA but the most common and popular way can be summarized in a few steps. Remember that a fault tree is used to analyze a single fault event and that one and only one event can be analyzed during a single fault tree. Even though the fault may vary dramatically, a FTA follows the same procedure for an event, be it a delay of 0.25 msec for the generation of electrical power, or the random, unintended launch of an (Intercontinental Ballistic Missiles) ICBM. FTA analysis involves five steps:

Define the undesired event to study: Definition of the undesired event can be very hard to catch, although some of the events are very easy and obvious to observe. An engineer with a wide knowledge of the design of the system or a system analyst with an engineering background is the best person who can help define and number the undesired events. Undesired events are used then to make the FTA, one event for one FTA, no two events will be used to make one FTA.

Obtain an understanding of the system: Once the undesired event is selected, all causes with probabilities of affecting the undesired event of 0 or more are studied and analyzed. Getting exact numbers for the probabilities leading to the event is usually impossible for the reason that it may be very costly and time consuming to do so.Computer software is used to study probabilities; this may lead to less costly system analysis.

Systems analysts can help with understanding the overall system. System designers have full knowledge of the system and this knowledge is very important for not missing any cause affecting the undesired event. For the selected event all causes are then numbered and sequenced in the order of occurrence and then are used for the next step which is drawing or constructing the fault tree.

Construct the fault tree: After selecting the undesired event and having analyzed the system to know all the causing effects (and if possible their probabilities) we can now construct the fault tree. Fault tree is based on AND and OR gates which define the major characteristics of the fault tree.

Evaluate the fault tree: After the fault tree has been assembled for a specific undesired event, it is evaluated and analyzed for any possible improvement. This step is as an introduction for the final step which will be to control the hazards identified. In short, in this step it is not required to identify all possible hazards affecting the system in a direct or indirect way the system.

Control of the hazards identified: This step is very specific and differs largely from one system to another but the main point will always be that after identifying the hazards all possible methods are pursued to decrease the probability of occurrence Figure 91.

Fault trees are developed using gate and events symbols. A gate may have only one input and one or more outputs. Dhillon and Kapur have defined the following common gate and event symbols for use in FTA.

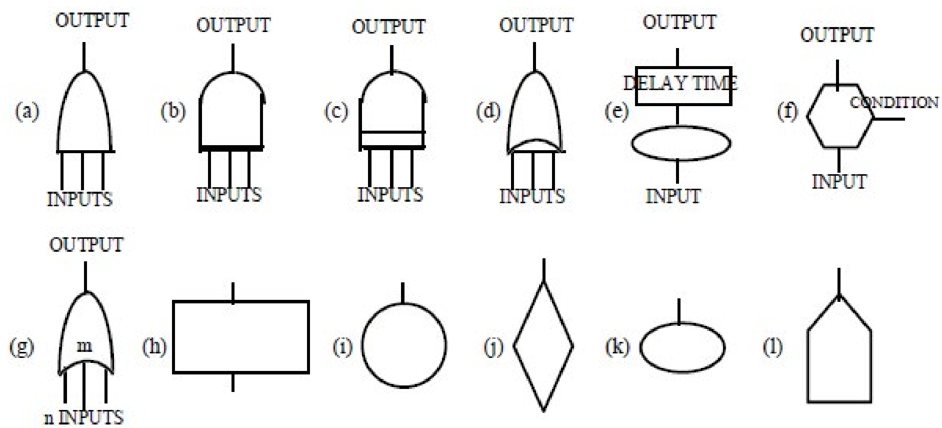


Figure 91: Control of the hazards identified.

- OR Gate: used when output event occurs when one or more input events occur.
- AND Gate: used when output event occurs when all input events occur.
- Priority AND Gate: like AND gate but input events occur in a specified order.

- Exclusive OR Gate: used when output occurs when one and only one of the input events occur.
- Delay Gate: used when output event occurs after a specified time delay.
- Inhibit Gate: used when output event occurs based on a conditional event occurring.
- M-out-of-N Gate: used when output event occurs based on an m out of n input events occurring.
- Resultant Event: used to represent an event resulting from some combination of preceding fault events.
- Basic Fault Event: used to represent failure of component or subsystem.
- Incomplete Event: used to represent a fault event whose cause has not yet been determined.
- Conditional Event: used to represent the condition associated with an Inhibit gate.
- Trigger or Switch Event: used to examine special cases by forcing events to occur or by forcing them not to occur.

Equation for FTA:

ab = ba	(cumulative law)
a + b = b + a	(cumulative law)
(a + b) + c = a + (b + c) = a + b + c	(associative law)
(ab) c = a (bc) = abc	(associative law)
a (b + c) = ab + ac	(distributive law)

Quantitative risk analysis for very large floating structure for offshore aquaculture structure

Failure probability: A mooring device is failed when the mooring reaction force W, due to oscillation of the floating structure, exceeds the yield strength R. The floating structure drifts when all its mooring devices are failed.Failure of a mooring device indicates presence of an event satisfying the following condition:

$$Z_k(t) = W_k(t; X) - R_k > 0 \qquad 0 \le t \le T \tag{1}$$

Where X is natural condition parameters, T duration of the natural condition parameters and R_k the random variable for the final yield strength of mooring device k, X and R_k are independent of each other.

The probability of a multi-point mooring system being failed by strong wind and waves in specified service life is given by the following equations:

$$P_f(T) = \iint dx_i dr_k$$
$$\text{Prob}\left[\bigcup_{k=1}^{m} Z_K(t) > 0, 0 \ge t \ge T \middle| X = x_k, R_K = r_k\right] \tag{2}$$

Where Prob [A|B=C] is the probability of under the condition of B=C and $f_x(x)$ and $f_R(r)$ are probability density functions of natural condition parameters and final yield strength of mooring device, respectively. Using the extreme-value distribution of the annual maximum values as the distribution of natural condition parameters, we define the annual reliability as follows:

$$R(T) = 1 - P_f(T) \quad (3)$$

The total reliability for years of service life is approximated by the following equation:

$$R_N(T) = \left(1 - P_f(T)\right)^N \quad (4)$$

Estimation of failure probability

The governing equation for oscillation of the floating structure is defined as follows:

$$F = \left[M_{ij} + m_{ij}(\infty)\right]X(t)'' + F_v(\dot{X}) + \sum_{j=1}^{n}\int_{-\infty}^{t}\dot{x}_j(\tau)L_j(t-\tau)d\tau + F_M(X,\dot{X}) \quad (5)$$

$$F = F_{wind}(t) + F_1(t) + F_2(t)$$

where : displacement vector of horizontal plane response of the floating structure; M_{ij}: inertia matrix of the floating structure; $M_{ij}(\infty)$ added mass matrix at the infinite frequency; F_v: viscous damping coefficient vector; L_{ij}: Memory influence function; F_M: Mooring reaction force vector; F_{Wind}: Wind load vector, F_1 and F_2: first and second wave force vectors respectively.

Estimation wave force: Wave force vector is generally expressed as the sum of linear wave force proportional to wave height and the slowly varying drift force proportional to the square of the wave height.See the equation below.

$$\begin{aligned} F(t) &= F_1(t) + F_2(t) \\ &= \int h_1(\tau)\zeta(t-\tau)d\tau + \int h_2(\tau_1,\tau_2)\zeta(t-\tau_1)\zeta(t-\tau_2)d\tau_1 d\tau_2 \end{aligned} \quad (6)$$

Where h_1 (T)h_2(T_1,T_2) are the vectors of impulse response function of wave force. ζ (t) is the time series of surface elevation of incident waves.

Estimation of risk of current load: Floating structure and the pressure drag for the lateral walls. Average wind velocity distribution on the horizontal plane is assumed uniform. The velocity profile in the perpendicular direction expressed using the logarithmic rule.For the fluctuating wind velocity, the mainstream direction (average wind velocity direction) is the sole element of consideration. The power spectrum of fluctuating current load is given in the following equation that considers spatial correlation:

$$S_{FF}(f) = \rho_a^2 \iint_A C_{di}(f)C_{dj}(f)U_iU_j \operatorname{Re}\left[R_{ij}(f)\right]\sqrt{S_i(f)S_j(f)}dA_idA_j \quad (7)$$

The spatial correlation is defined as follows:

$$R_{ij}(f) = \exp\left(-\frac{k_1 f\left|y_i - y_j\right|}{\sqrt{U_iU_j}}\right)\exp\left(i\frac{k_2 f\left(x_i - x_j\right)}{\sqrt{U_iU_j}}\right) \quad (8)$$

Where ρ_a: air density, U: average wind velocity, d_A: area element of the floating structure surface, C_d: drag coefficient, S (f): power spectrum of fluctuating wind, x: coordinate in the main stream direction of plane element, y: coordinate at right angles to the mainstream direction of plane element, k_1: spatial correlation coefficient at right angles to the mainstream and k_2: spatial correlation coefficient in the direction of mainstream.

Estimation natural environmental condition: Assuming yield strength R is a deterministic value and wave height and others are a function of wind velocity, in equation as given below. This enables us to calculate annual initial failure probability from the distribution of the conditional failure probability and the distribution of the probability of annual maximum current velocity.

$$P_f = \int_B^\infty P\left[T \middle| U_{10}\right] f(U_{10}) dU_{10} \tag{9}$$

Where P [T| is conditional initial failure probability during duration time T and f (U_{10}) probability density function for annual maximum wind velocity. The lowest value B for integration varies with which extreme value distribution the conditional failure probability is approximated by the equation.

Assessment of functional and serviceability: Modern safety criteria for marine structures are expressed by limit states as indicate in the Table 40 below and are briefly outlined in the following. This will be applied to stages of risk and reliability assessment and analyzing the system required.

Limit State	Description	Remarks
Ultimate (ULS)	Overall structure stability. Ultimate strength of structure. Ultimate strength of mooring system.	(Not relevant for VLFS) Component design check
Fatigue	Failure of joint-normal welded joins in hull and mooring system.	Component design check depending on residual system strength after fatigue failure.
Accidental collapse (ALS)	Ultimate capacity of damaged structure (due to fabrication defects or accident loads) or operational error.	System design check
Serviceability (SLS)	Structure fails its serviceability if the criteria of the (SLS) are not met during the specified service life and with the required reliability	Disruption of normal use due to excessive deflection, deformation, motion or vibration.

Table 40: Safety Criteria (e.g. ISO,) [87].

Expected result from quantitative analysis: The expected results of this study analysis are declared from based on the methodologies applied to the study analysis. In Figure 92 it is expected to obtain the probability of exceedance of the mooring reaction relative to average current velocity.

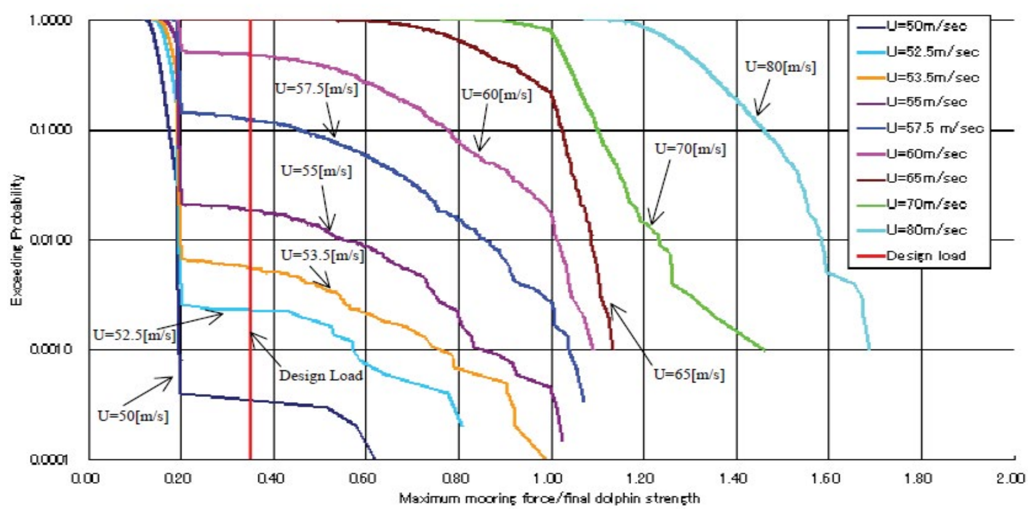


Figure 92: Graph of quantitative analysis.

The Figure 93 shows example of the extreme value distribution of annual maximum current velocities graph based on natural environmental condition that shows below.

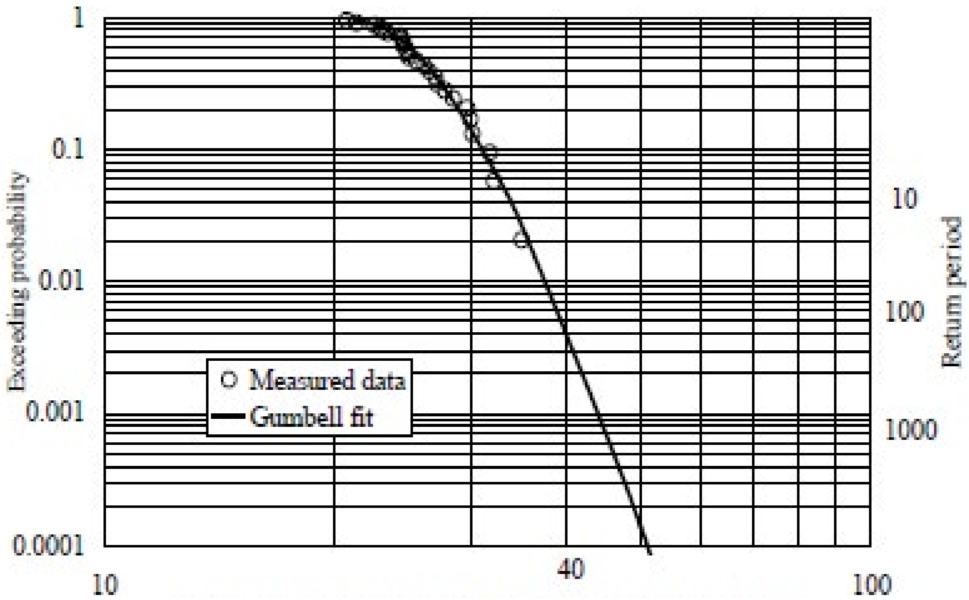


Figure 93: The extreme value distribution of annual maximum current velocities graph.

In Figure 94 expected require conditional failure probabilities and mean current reliability could be obtained.

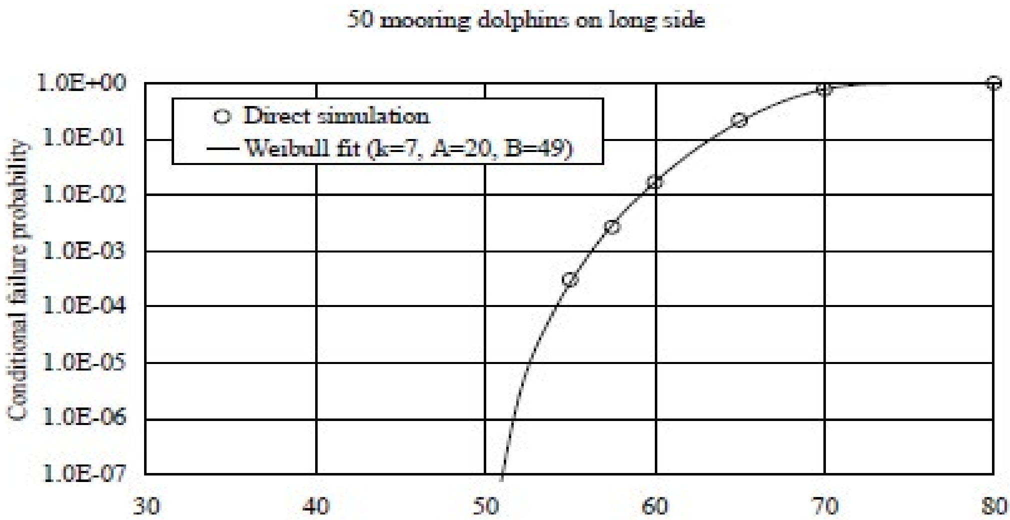


Figure 94: The conditional failure probabilities and mean current reliability.

Figure 95 shows expected result for variation of failure probability to a number of mooring on the system.

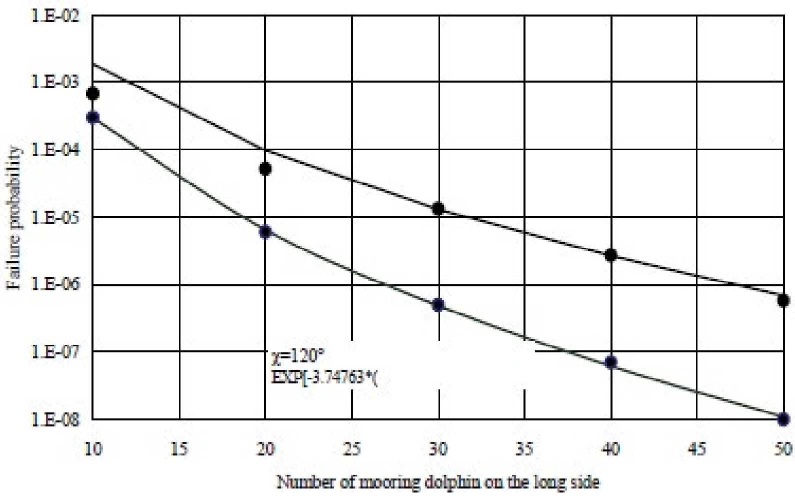


Figure 95: The variation of failure probability to a number of mooring on the system.

The expected results will help to make discussion and decision to make sure the study analysis achieve the objectives required. Other relevant plot of the result will be produced.

8. Qualitative Method for Antifouling Long Life Paint for Marine Facilities or System

Abstract

Fouling is a major problem to shipping industry.Hull fouling reduces the fuel efficiency and speed of affected ships, increase in frequency of ship dry dockings, reduces propeller efficiency and accelerated corrosion rate. Antifouling paints are used to coat the underwater area of ships to prevent organisms such as algae and molluscs attaching themselves to the hull of the ship. As a result, antifouling paints which are alternatives to TBT systems such as Controlled Depletion Systems (CDPs), Tin-Free Self-Polishing Copolymers (tin-free SPCs) and foul release systems were developed in marine industry. However, most of these paints cannot last for long because misapplication. Paint is not a finished product until it has been applied and dried on an appropriate substrate at the designed performance film thickness. High performance paint systems are especially sensitive to misapplication and knowledge of the paint characteristics. Also recommended film thickness is vital to obtain optimum results to improve paints performance and reduce maintenance cost. Therefore, proper application is critical to the performance of the paint system. This paper presents the result of study made on the problems of fouling on ship hull structures and deduced a qualitative model for ship paints application in order to prolong the life span of antifouling paint.

Keywords: Antifouling; Application; Hull Fouling; Paint; Qualitative

Introduction

Performance of ships depends on their speed and power generated. Like wise, economic and efficiency of ship operation is achieved at optimum speed, power and according to frequency of dry docking of ship. Hull fouling poses a lot of hindrances to design power and efficiency of ship. Fouling refer to the accumulation of unwanted material on solid surfaces in an aquatic environment. The fouling material can consist of either living organisms (biofouling) or a non-living substance (inorganic or organic).

Marine fouling is a perennial problem for vessels, ports and anything kept in the sea for a period of time. The sea is teeming with the tiny larvae of marine organisms that swim around until they find somewhere to settle and grow. Smooth surfaces are particularly attractive to many of these creatures, and are quickly encrusted. This slow down ships in seaways, block pipes and speed up corrosion. This study focuses on the problems of ship hull fouling which hull fouling reduces fuel efficiency and speed of affected ships, consequently increases their operating costs due to the increase in frequency of ship dry docking.It also reduces propeller efficiency [93,94] and accelerates corrosion [95].

In order to lessen hull fouling, antifouling paints are used to coat the bottoms of ships to prevent organisms such as algae and molluscs attaching themselves to the hull,that result to the slowing down of the ship and thus increasing fuel consumption. The new IMO convention defines antifouling systems as a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organism. Biocidal anti-fouling paints have been applied to the bottoms of ships for decades. The paints slowly leach into the water, killing anything attached to the ship hull but leachates have been found to accumulate in harbors and the sea.

Among all the different solutions proposed throughout the history of navigation, Tributyltin (TBT) paints have been one of the most effective deterrents to hull fouling organisms, but studies have linked TBT accumulations to deformations in oysters and sex changes in whelks. As a result, restrictions on the usage of TBT in vessels were imposed. The International Maritime Organization (IMO) adopted the Antifouling Systems (AFS) Convention in 2001. The Convention called for a global ban on the application of TBT-based antifouling paints by 1st January 2003 and the prohibition of the presence of such paints on the surface of vessels by 1st January 2008. National bans on the use of the TBT paint will result in an increased hull fouling, unless environmentally friendly replacement paints are accepted by the shipping industry.

The paint industry has been urged to develop environmental friendly TBT-free products able to replace the TBT-based paint that yield the same economic benefits and cause less harmful effects on the environment. There are Controlled Depletion Systems (CDPs) and tin-free self-polishing copolymers (tin-free SPCs).CDPs are upgrade of traditional soluble matrix technology by means of modern reinforcing resins.The reaction mechanisms are assumed to be equivalent to those of conventional rosin-based AF paints. The tin-free SPCs are designed for the same reaction mechanisms with sea water as Tributyltin Self-Polishing (TBT-SPC) paints.

There is another type of antifouling paint that may replace the TBT-based antifouling paints which is foul release systems. Foul release systems are non-toxic and made of silicone elastomers of low surface energy. This low surface energy inhibits the ability of fouling organisms to attach strongly to the surface. Paint is not a finished product until it has been applied and dried on an appropriate substrate at the designed performance film thickness. When the paint is applied to the exterior layer to a ship hull, it is subject to a variety of parameters that can degrade the paint and reduce its useful life-span. These parameters need to be taken into consideration during ship paints application. Thus, ship paints application procedures are very important in order to enhance the performance or quality of antifouling paints. The parameters which need to be considered during application of the paints to the ship hull include surface preparation, paint application, paint materials, curing time, environmental conditions, locations, personal quality, inspections and others.

The performance of any paint coating depends on the correct and thorough preparation of the surface prior to coating. The most expensive and technologically advanced coating system will fail if the surface preparation is incorrect or incomplete. Additionally, methods of applying the paints are by brush, roller, conventional (air) spray, conventional (pressure pot) spray and airless spray. Although the application methods are very important, the application technique or skills of personnel also play a vital role. When applying marine paints the most important factors to consider are the condition of the substrate, the surface temperature, and the atmospheric conditions at the time of painting. Appropriate ship paint materials can effectively prevent attachment or accumulation of fouling on the ship hull bottom.Furthermore, inspection by the coating inspector is necessary to make sure the coating is properly applied.

This study seeks to examine the related issues of Antifouling (AF) paints, ship paints application and aims to deduce fouling prevention systems and enhance the performance of antifouling paints. This includes the study of biology of the fouling process, historical development of AF paints and also the proper way for ship paints application. The historical description leads to a discussion of Tributyltin (TBT)-based systems, tin-free biocide-based and non-toxic alternatives replacements. Proper paint application is critical to the performance of the paint system. This study will use historical data of antifouling paints to determine the parameters for ship paints application. Finally, a qualitative model for ship paint application to enhance the performance of antifouling paints is deduced.

Methodology

The model design is for the ship paint application procedure. This is produced through interview carried out with the ship yard personal in MMHE and M-Set. Data are collected from Painting and Blasting Department, reviewed about ship painting process and interview with the Classification Society and Paint Maker in order to get the further information. This is to make sure the procedure is compliance with the standard and IMO requirement. Data is analysed by considering the whole ship painting process and how the ship painting procedure is carried out according to the standard. And the analysis leads to deduce a qualitative model for ship paint application procedure.

Results and Discussion

The model is produced with the intention of giving a guideline for all level of personnel on the standard of workmanship in the ship repair division, especially, the blasting and painting parts in order to satisfy ship owners and classification societies. This model indicates the elements accuracy to be kept in the process of blasting and painting repairs or modifications and the finished quality obtained.

The model is developed from several references, historical data and case study related to antifouling paints. The model can serves as a guideline of the standard of workmanship for painting process that mitigates fouling of ships hull. The quality of the end product relies on the whole ship paint application process. Thus, we must always keep in mind that Quality is built in the process, not in the inspection.

Existing flow chart for ship paint application Figure 96:

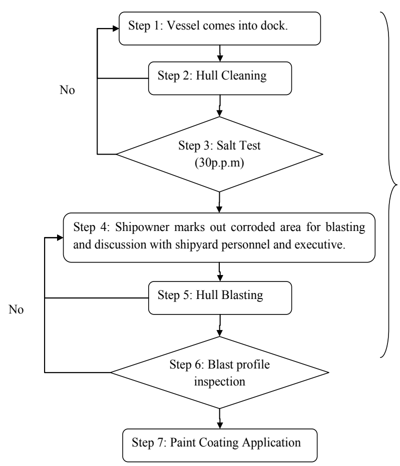


Figure 96: Flow chart for ship paint application.

From the existing ship paint application above, I found the gaps to improve the existing procedure. The improved ship paint application flow chart is showed in Figure. This flow chart can make the paint application becomes more efficient.

Improved flow chart for ship paint application Figure 97:

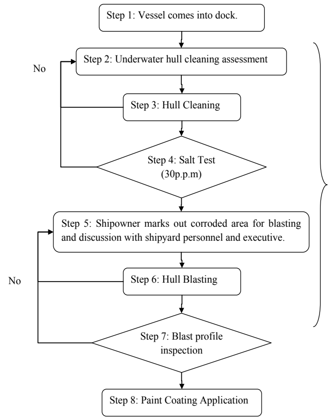


Figure 97: Improve Flow chart for ship paint application.

From the improved ship paint application flow chart above, I have added one step from the previous flow chart in order to optimize the existing procedure. This improved flow chart can make the paint application become more comprehensive, concise and efficiency.

Vessel comes into dock: Since it is a class requirement, for each vessel needs to come into dock to undergo the bottom survey inspection of its underwater area every two and half years.Vessel will be put in the dry dock upon arrival in the shipyard. The vessel will be moored into the dock and when it had successfully sat on the keel blocks, the water in the dock will be pumped dry.

Underwater hull pre-cleaning assessment: The step for the inspection process is to conduct an underwater assessment of the fouling growth that has occurred since the last inspection and evaluate the coating condition. This will be completed before any hull cleaning is performed. Normally, ship hull can be divided into 6 quadrants as showed in Figure 98. The six quadrants are: I-starboard forward, II-starboard aft, III-port aft, IV-port forward, V-starboard waterline and VI-port waterline.

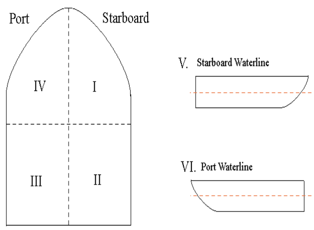


Figure 98: Hull quadrants [96].

Fouling assessment: Fouling growth on each boat hull will be evaluated on a 0-5 scale. 0 represents the optimal condition and 5 the worst condition. Table 41 determines the numeric ratings and provides a description of what type of fouling growth is associated with each rating. The paint maker's inspector will record the fouling rating for each quadrant and provide any additional observations or comments, such as noting the type of fouling present on the hull surface.

*0 is best condition, 5 is worst condition, ** Coral is the local term used for limestone tubes of worms that grow on the coating's surface.

Rating	Fouling Growth
0	No silting, biofilm or fouling growth present.
1	Light silting or biofilm. Little to no discoloration; Paint surface still clearly visible beneath.
2	Heavy biofilm; Light to moderate silting as indicated by discoloration (a solid, discernible, physical layer); Painted surface may be slightly obscured.
3	Low to medium levels of fouling present; Dark algae impregnation; Hard growth may be present (tubeworms, barnacles, bryozoans, etc.); Painted surface definitely obscured.
4	Medium to high levels of fouling present; Hard growth present, such as tubeworms, barnacles, bryozoans, etc.; Macrofoulers may include mature forms that may be densely grouped; Paint surface no longer visible beneath fouling in areas.
5	High levels of fouling present; Lengthy, soft algae and hard, tube worms and possibly barnacles impregnating the coatings; Macrofoulers may be densely grouped; Coral** growth can be seen to extend out from the hull; Paint surface no longer visible beneath fouling.

Table 41: Fouling rating scale.

Coating condition assessment: Coating condition for the entire hull need to be evaluated based on Table 42 which identifies the rating scale of coating condition. The colour of undercoat also need to be recorded when the coating was applied to the ship hull. Ratings of 1-3 represent antifouling painted surface appearance associated with normal physical wear due to underwater cleaning action or hydrodynamic effects. Ratings 4 and 5 indicate either excessive cleaning actions or blistering due to internal failure of the paint system.

Rating	Coating Description
1	Antifouling paint intact, new or slick finish. May have a mottled pattern of light and dark portions of the original paint colour.
2	Shine is gone or surface lightly etched. No physical failures.
3	Physical failure on up to 20% of hull. Coating may be missing from slightly curved or flat areas to expose underlying coating.Coating has visible swirl marks within the outermost layer, not extending into any underlying layers of paint.
4	Physical failure of coating on 20-50% of bottom. Coating missing from slightly curved or flat areas to expose underlying coating.Coating missing from intact blisters or blisters which have ruptured to expose underlying coating layer(s). Visible swirl marks expose dunderlying coating layer.
5	Physical failure of coating on over 50% of bottom. Coating missing from intact blisters or blisters which have ruptured to expose the underlying coating layer(s).Visible swirl marks exposed underlying coating layer.

Table 42: Coating condition rating scale.

Surface preparation: Good surface preparation is one of the most important process of the entire coating procedures, as great percentage of coating failures are usually associated with poor surface preparation. All paint systems will fail prematurely if the surface preparation is not done according to standard procedures requirement. If contaminants such as loose rusts, oil, grease, dirt, salts, chemicals, dusts, etc are not removed completely from the surface intended for coating, the paint adhesiveness as well as cohesiveness and its quality would be affected. Osmotic blistering would also occur resulting in premature failure of the coating in service. There is no paint system that would give optimum performance result over a poorly prepared steel surface.

Hull cleaning: There are various methods available for cleaning and preparing steel surfaces prior to painting. The choice and methods of surface preparation would depend on the location where the intended area of the vessel is required and the availability of equipment to be used. Hull cleaning includes hard scrap and fresh water washing. Hard scraping shall be carried out to remove slimes, weeds, shells, barnacles, etc. Besides that, approved detergents shall be used to remove any oil or grease present on the hull.

Hull cleaning standard by fresh water: Surface preparation by using fresh water can be divided into 4 levels. Table 43 is the levels or categories for fresh water surface preparation:

Fresh Water Washing/Pressure	Cleaning Quality
Low Pressure Water Washing Pressure: Less than 68 bar (1000 psi)	It can remove surface salts, dust and loose surface debris.
High Pressure Water Washing Pressure:Between 68-680 bar (1000-10000psi)	For 68-204 bar (1000-3000 psi) It can remove salts, dirt, loose coatings and leached layer of antifouling coatings. For 204-680 bar (3000-10000psi) It can perform selective removal of coatings and intact coatings.
Fresh Water Washing/Pressure	**Cleaning Quality**
High Pressure Hydro-Blasting (Water-Jetting) Pressure: Between 680-1700 bar (10000-25000 psi)	It can remove all existing old paint or heavy rust. It scales to WJ 3 (Water jetting standards NACE 5/ SSPC-SP 12) to a uniform matt finish with at least two thirds of the surface being free of all visible residues (except mill scale) and the remaining one-third containing only randomly dispersed stains of previously existing rust, coatings and foreign matter.
Ultra High Pressure Hydro-Blasting (Water Jetting) Pressure: Above 1700 bar (25000 psi), but normally 2000-2800 bar (30000-40000psi)	It can remove all existing old paint or heavy rust. It scales to WJ 2 hydro jetting standard of uniform matt finish with at least 95% of the surface area being free of all previously existing visible residues and the 5% containing only randomly dispersed stains of rust, coating and foreign matter.

Table 43: Categories for fresh water surface preparation.

Salt test: The purpose of carrying out the salt test is to prevent coating failure due to effects of salt elements on the surface before coating. In order to prevent the defect, salt test is carried out to measure the level of salt and to make sure that salt content is at minimum level. Normally, salt test is carried out by using Bresle kit sampler. Figure 99 showed the flow chart of salt test measurement by Bresle kit sample.

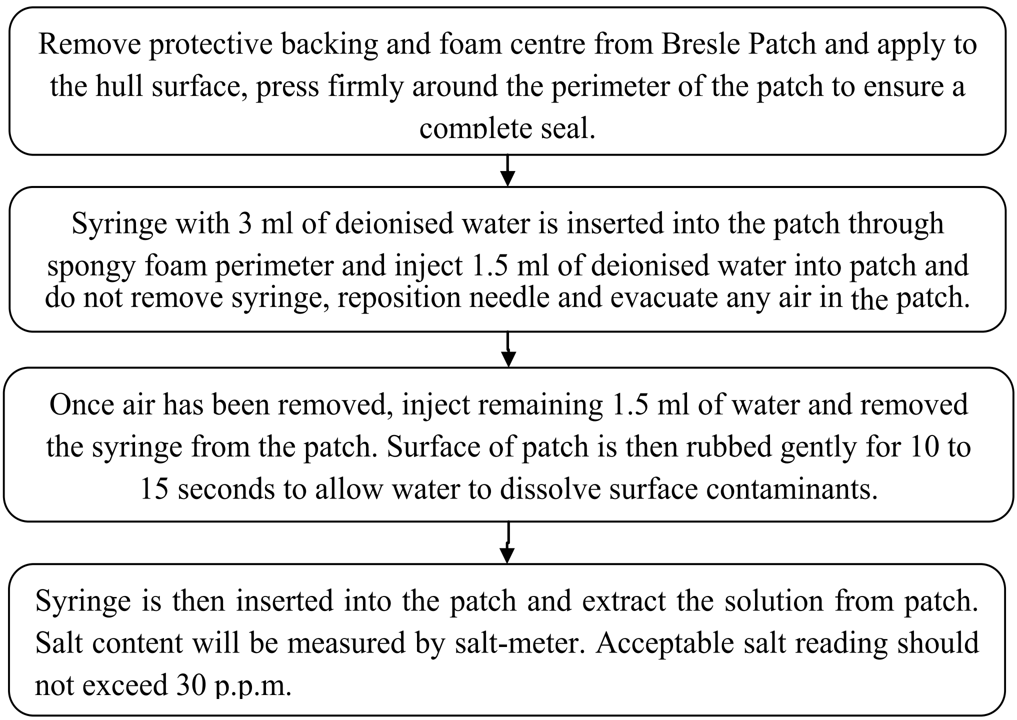


Figure 99: Hull quadrants [96].

Condition of ship hull (side shell area) prior to grit blasting: Next, the Owner's representative will mark out the corroded area for blasting based on rust grade and shall discuss it with the Yard's Painting executive. There are four types of rust condition using Swedish Standard which listed in Table 4. When all parties had agreed on the total blast area and the blasting grade, a Proposed Side Shell Blasting and Painting Area shall be signed and endorsed Figure 100.

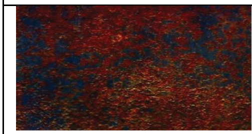
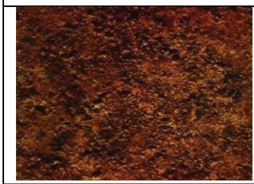
 Rust Grade A	Steel surface largely covered with adhering mill scale with little, if any rust.
 Rust Grade B	Steel surface has begun to rust and from which mill scale has begun to flake.
 Rust Grade C	Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.
 Rust Grade D	Steel surface on which the mill scale has rusted away and on which pitting is visible under normal vision.

Figure 100: Hull quadrants [96].

Shipyard shall draw up a work schedule based on the agreed areas and instruct the blasting contractor to proceed with the blasting works. The blasting time of inspection is usually divided into two sessions, once before noon and another late in the evening. This is to allow sufficient time for the blasters to produce a larger blast area so that when the paint is mixed and applied; there will not be much wastage for the coverage.

Grit blasting: Grit blasting is the commonly used method for preparing a surface for the application of paint. When properly carried out, grit blasting can remove old paint, rust, salts, fouling, etc., and provides a good mechanical key (blast profile) for the new coating. Copper grit is one of the blast media widely used for blasting in shipyard and is obtained as cooper slag waste from melting the copper metal at a very high temperature. It is a by-product and is often referred to as hard coarse-grained silicieous sandstone. This is the base for grit and can be found or prepared in different sizes for different types of blasting known as grit blasting. It usually comes is sizes ranging from 830cc (meshes) and 1030cc but most shipyard prefers the former over the latter because of its coarseness and larger size in order to achieve a higher blast profile on the steel substrate. Besides that, it is important that the correct blast profile is achieved before the substrate is coated. Paint manufacturers should specify the blast profile for each coating, in terms of the pattern required for that paint. The instrument to measure the blast profile is called Blast Profile gauge and the reading is in micron. In general, thicker coatings will require a profile with a greater peak to trough measurement than a thin coating.

Blast cleaning standard: The most commonly referred standards are Steel Structure Painting Council (SSPC), National Association of Corrosion Engineers (NACE) and Swedish

Standards or International Standards Organization (ISO). Each standard is divided into four standards of cleanliness, broadly described as; brush off, commercial, near white metal and white metal. Whilst each standard may be differ slightly in requirements and terminology. The Table 44 indicates the grades for steel surfaces using blast cleaning.

	Brush Off	Commercial	Near-White Metal	White Metal
SSPC	SP 7	SP 6	SP 10	SP 5
NACE	No. 4	No. 3	No. 2	No. 1
SWEDISH	Sa. 1	Sa. 2	Sa. 2½	Sa. 3

Table 44: Preparation grades for steel surfaces using blast cleaning.

Blast profile: The correct blast profile is very important prior to painting. If the blast profile is produced too high, an inadequate coating coverage will result over any high and sharp peaks and this could lead to premature coating breakdown. However, grit blasting can also result in an insufficient surface profile and may simply redistribute contamination over the steel surface trapping contaminants under the surface. The blast profile measurement method by the testex profile tape is as below Figure 101:

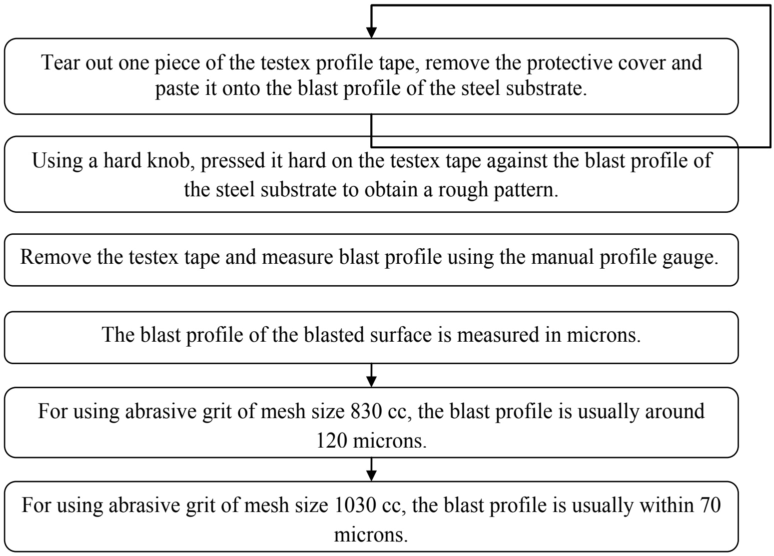


Figure 101: Flow chart of blast profile measurement by testex profile tape.

Paint application: The paint application is to provide a film which gives protection or decoration of ship hull being painted. The success of any application and subsequent performance depends on some variables such as surface preparation, film thickness of the paint system, methods of application and conditions during application.

Film thickness measurement: The Wet Film Thickness (WFT) of the coating is measured and can be converted to a Dry Film Thickness (DFT) following the paint maker's guidelines for that product. The wet film thickness measurement can be determined by how much coating should be applied to reach the specified DFT. The dry film or wet film ratio is based on percentage of solids by volume of the coating being used. The basic formula to measure the WFT is:

$$WFT = \frac{DFT(\mu m) \times 100}{VolumeSolid(\%)}$$

Ship side coating thickness range: Different ship side area has different Dry Film Thickness (DFT). Table 45 shows ship side coating thickness range.

Locations/Areas	Surface Preparation	DFT range, μm
Topside	1. High pressure fresh water wash (3000-5000 psi) 2. Grit blast Sa 2.0 or Sa 2.5	200-400 (epoxy)
Boot Top		150-300 (epoxy) 75-100 (tie coat) 150-200 (antifouling)
Vertical Side		200-300 (epoxy) 75-100 (tie coat) 250-300 (antifouling)
Flat Bottom		175-300 (epoxy) 75-100 (tie coat) 100-200 (antifouling)
Propeller		375-400
Rudder		500

Table 45: Ship side coating thickness range.

Method of paint application: Airless spray is now almost a universal method for ship side paint application. This is by far the most important and efficient method for the application of heavy-duty marine coatings, which allows the rapid application of large volumes of paint as well as the application of high build coatings without thinning. Airless spray method can reduce the overspray and bounce back problems. Moreover, it follows that ships paints must be formulated and manufactured to be suitable for application by airless spraying.

Airless spray is a technique of spray application which does not rely on the mixing of paint with air to provide atomization.Atomization is achieved by forcing the paint through a special and precise constructed nozzle or tip by hydraulic pressure. The choice of tip determines the film thickness applied per pass of the spray gun and should be selected in accordance with the coating manufacturer's guidelines. The speed of each pass and volume solids of the paint will influence film thickness. Airless spray equipment normally operates at fluid line pressure up to 5000 psi (352 kg/cm^2) and care should be taken periodically.

Modern products are most commonly applied by airless spray.One airless spray gun is capable of spraying between 50 and 80 litres of paint per hour, i.e. covering 150-400 m^2/hr at the required film thickness. Moreover, airless spray application produces less overspray than conventional air-assisted spraying but there is some risk of painters inhaling spray droplets. Antifouling compositions offer special problems because of the poisons they contain, this applies both to the older copper poison types and more particularly to the organometallic poisons. Thus, suitable protective equipment must be used.

Commonly, painting must be inspected regularly to ensure that specifications regarding surface preparation, wet and dry film thickness, drying times, mixing of two-pack materials, overcoating intervals, quality of workmanship and others are met.

Condition during application: There are some factors which must be considered during paints application. The major factors are condition of substrate, temperature, relative humidity, weather conditions and condensation. The proper ambient temperature for steel hull painting process should be 3°C above dew point. Most paints can tolerate high humidity but condensation must not form on the surface being painted. During the painting process for the ship hull, the relative humidity must below 85%. Furthermore, paint should not be applied during fog, mist or raining. Generally, under these conditions, it is difficult to maintain the steel temperature above the dew point. Besides that, condensation is forbidden during hull painting process.

Antifouling paints for the ship hull area: Generally, there are two basic mechanisms employed in coatings to prevent fouling settlement which are toxic antifouling and foul release coating.Toxic antifouling means that prevention of fouling by a surface coating requires the maintenance, in the water in contact with the coating, of a concentration of toxin that is lethal to all of the target organisms. Meanwhile foul release coating has a surface with very low surface energy which reduces the efficiency of the attachment process dramatically, i.e. a non-stick surface is presented to the organism.

Typical ship paints properties: Ship paints properties are very important for us to understand because this is important on choosing the correct and proper types of ship paints. The Table 46 shows the properties of the ship hull painting systems most commonly used in the marine industry.

Coating compatibility: Coating compatibility is important when the maintenance or repair work is carried out, to ensure that the repair coat will adhere to the original paint, otherwise failures will occur between the individual layers (inter-coat adhesion failure). Incompatibility between coating types, such as epoxy anticorrosive coatings with some types of antifouling paints, can be overcomed by the use of a tie coat, which has good adhesion to both paint types and is therefore applied onto the anti-corrosive layer before the antifouling layer is applied. Thus, paint compatibility is a factor which must be takes as consideration.

Performance of antifouling paints determined by hull roughness: Ship's underwater hull is painted to protect the substrate and also prevent undue roughness. The most significant cause of hull roughness is fouling. Normally, paint fouling control technology can be characterized into 4 types: Controlled Depletion Polymer (CDP), TBT Free Self Polishing Copolymer (SPC), Hybrid TBT Free Self Polishing Technology and Foul Release Technology. Each type of paint fouling control technology has different Average Hull Roughness (AHR) value. Table 47 shows the AHR value for these 4 types of AF paints. The paint fouling control which has smallest AHR value has lower percentage increase in power needed or fuel used. Thus, foul release technology can save more power and fuel used.

Paint Type	Drying Mechanism	Properties			Area of Use	
		Mechanical	Cosmetic	Overcoatability	Under water	Above Water
Acrylic	Physical	Moderate	Very Good	Good	antifouling	⁄
Alkyd	Oxidative	Moderate	Good	Good	-	⁄
Bituminous	Physical	Poor	N⁄A	Very Good	⁄	-
Chlorinated Rubber	Physical	Moderate	Moderate	Very Good	⁄	⁄
Epoxy	Chemical Cure	Very Good	Poor	Poor	⁄	⁄
Epoxy-Ester	Oxidative	Moderate	Moderate	Good	-	⁄
Epoxy-Tar	Chemical Cure	Good	N⁄A	Moderate	⁄	-
Polyurethane	Chemical Cure	Very Good	Very Good	Moderate	-	⁄
Polyurethane-Tar	Chemical Cure	Good	N⁄A	Moderate	⁄	-
Vinyl	Physical	Good	Good	Very Good	-	⁄
Vinyl-Tar	Physical	Moderate	N⁄A	Very Good	⁄	-
Zinc Silicate	Moisture Cure	Very Good	N⁄A	Very Poor-Self to Self Good-with epoxies	-	⁄

Table 46: Typical ship paints properties.

Types of paint fouling control technology	Average Hull Roughness (AHR)
Controlled Depletion Polymer (CDP)	40 microns/year
TBT Free Self Polishing Copolymer (SPC)	20 microns/year
Hybrid TBT Free Self Polishing Technology	30 microns/year
Foul Release Technology	5 microns/year

Table 47: Average Hull Roughness (AHR) value for antifouling paints.

Antifouling systems regulations and convention: Generally, antifouling system has their regulation to control the harmful antifouling systems on ships. This is very important for us to understand in order to enable the ship become compliant. In this research, I include Antifouling System (AFS) requirement and the Convention and Best Management Practices on marine pollution by removal of antifouling coatings from ships. From the AFS requirement, there is a prohibition on the application or re-application of organotin compounds which acts as biocides in antifouling systems. When existing vessels replaced the antifouling after 1 January 2003, they complied with this requirement or provided sealer to avoid a non-compliant antifouling to avoid leaching. All vessels after 1 January 2008 shall either not bear such compounds on their hulls or external parts or surfaces; or apply coating that forms a barrier (sealers) to such compounds such as leaching from the underlying non-compliant antifouling systems.

Furthermore, Convention and Best Management Practices is to prevent marine pollution by the removal of ship antifouling coatings. Thus, management for AFS waste collection is very important throughout the process. The adoption of management practices for the application and removal of antifouling systems can reduce of biocides into the natural environment. The aspects include choice of antifouling system and collection, treatment and disposal of spent coatings which have an impact on the release of biocides into the environment. If not managed properly, it may result in high concentrations of biocides in the marine sediments in areas close to where application and removal activities are conducted.

Quality assurance: Each model has their own standards in order to make sure the standard is controlled and complied with the rules and requirements. To ensure the model is controlled efficiently, quality assurance plays an important role. The purpose of a quality assurance system is to prevent problems from occurring, detect them when they do, identify the cause, remedy the cause and prevent recurrence. Quality Assurance mechanism in this model is to ensure that accuracy and precision throughout a procedure. The parties involved in this procedure include Yard's Painting executive, Shipowner's representative, suppliers, Paint Manufacturer and Surveyors. The responsibility of Yard's Painting executive is to use checklists and inspection records to ensure the standards are followed. Besides that, they will conduct audit by QA department on a monthly basis.If t sign of any incompliance is found, yard person such as Project Manager will issue Quality Assurance Note (QAN) or Non Conformance Report (NCR) towards suppliers. QAN is only for light or small incompliant but NCR is for heavy incompliant.

Furthermore, Paint Manufacturer's inspector must have a widely experience and good judgement in order to make sure the paint job was completed as specified. They need to take concern on many aspects throughout the painting process. Adhesion test or dolly test which is commonly known among the paint inspectors, would have to be carried out when the external hull of the ship is being grit blasted and applied fresh coatings. This is to ensure the paint adhesion onto the substrate hull can withstand a pull-out pressure of not less than 300 psi. The higher the pressure of the pull-out test, the stronger the adhesion of the paint onto the steel substrate is. All parties must take concern on their responsibilities to ensure the quality obtained is in compliance. Every daily log, tests and inspections work must be recorded for future evaluations of the painting. There are no any by-pass steps that can be skipped. Throughout the process above, the quality of the paint is assured.

Conclusion

Fouling is unwanted accumulation material on solid surface. There is either living organism (biofouling) or non living substance. Antifouling paints are used to prevent the biofouling. There are two types of antifouling paints which are toxic and non-toxic alternatives to TBT systems. Nowadays, there is a trend to use the foul release technology which is also known as non-toxic alternatives to TBT systems such as silicon-type foul release AF paint. This product is expensive and requires longer working period to accomplish but the long term benefits can be seen from the smooth and faster speed of the vessel reaching its destination and it's cost effective saving which is believed to be about 40%. According to LNG Carrier Owners Manual, foul release coatings are proving themselves to be the ideal solution for LNG hull and propeller fouling control. Not only can they keep hulls and propellers smooth and free of macro-fouling for extended service period of up to 60 months but in addition, since they do not use biocides to control fouling, they can be an integral part of an LNG environmental management plan.

Further more, ship paint application is the most important part to control the performance or quality of antifouling paints. High performance paint systems are especially sensitive to misapplication and knowledge of the application characteristics and recommended film thickness is vital to obtain optimum results. For optimum service life, the surface must be completely free of all contaminants that might impair performance and should be treated as such to assure good and permanent adhesion of the paint system. The quality of surface preparation has a direct relation with the lifetime of a system. Nowadays, the paint application method commonly used airless spray. The degree of skill of the personnel can affect the performance of paints. Besides that, paints materials, coating compatibility and environmental conditions also need to be concidered. Different paints materials have different properties, thus have different effects on the paints performance.

Throughout the whole ship painting process, it is necessary to inspect the work as it progresses if there is to be any reasonable assurance that a paint job was completed as specified. There are many failure cases due to poor workmanship occurred after the work has been completed and has been paid for. Beside that, quality assurance is part of quality management focusing on increasing the ability to fulfill requirements of the process. As a conclusion, the model results are complied with the standard requirements.

Recommendation

There are many aspects in this research which could be investigated in the future. Some suggestion and recommendations on future study are as follow:

- The practical way to measure hull fouling is to use a professional diver to not only measure but to survey or inspect the general condition of the hull as a whole and record with video camera or CCTV. This is because hull fouling varies along the hull.
- There are many ship paints application methods discussed in this paper Therefore, it is suggested that investigation for each methods in much more details.
- The performance of AF paints can be determined by many factors. Thus, it is suggested that investigation for performance or quality of AF paints to be done in much more detail.

9. Safe Mooring and Berthing Protection System Analysis for Marine Facilities

Abstract

Waterway and port development work involves laborious activities and sub sequential use of large amount of energy. Efficient berthing and mooring is a function of safety and environmental conservation. Most inland waterways; lack facility for berthing. Heavy seaborne traffic in port leads to the requirement of port terminal development or improvement. Marine terminal involved problem related to traffic and high cost. Availability of modular navigation facility (fender and anchor) for safe berthing and mooring, prevent accident occurrence, compensate of uncertainty and subsystem risk consideration factors. It also facilitate use of modular facility that reduce labour require, energy usage, hence carbon footage has gain approval of efficient product development in recent year. The use of such mobile equipments equally gives advantage to port to reduce port traffic, safety preservation of environment reduction in maintenance and berth allocation and reduction in accident related to loss of mooring function or hit on navigation structure. The study involved design

of a safe mooring system and selection of safe loading and unloading facilities to ensure the smooth safe navigation activity in waterway and reduction in the work delay. The berthing facility is moveable, floating structure that acts as a protection for ships safe berthing and mooring in waterway. The analysis involve design that determine the safe berthing velocity, the berthing energy, environmental load (wind and current) and material which are the important parameters for fender selection and to ensure that it is safe to carry out its function for safe mooring, loading and unloading activities. The use of light weight material, less energy can be employ for berthing and mooring for waterway operation, and provision of safety for the system can be discount for environmental conservation. The result of this study hoped to improve safety and efficiency mooring and berthing in waterway and port operation and handling of the ships entering and leaving the marine terminal and waterway.

Introduction

Worldwide seaborne traffic at inland waterways and ports is continually growing. This bring along high demand for ships from shipbuilding companies and also jetty constructions. Waterway and port operators need to enhance the facilities in the ports so that they can compete with the other competitors. Due to the restriction of the capital to build the facilities that need a lot of money for example jetty, berth required in order reducing the heavy seaborne traffic which is a burden to the port owner. A cost effective way alleviate such burden for port owner is to acquire floating pier which act as loading and unloading floating pier. Floating piers are much less costly compare to building a jetty or berth. Marine fenders and anchor are crucial to a ship berth. A proper fender design should effectively absorb or dissipate the kinetic energy carried by a docking ship and thus mitigate the impact force to a sustainable level [97]. Fender and anchor selection normally involves extensive trade-offs depending on the type, purpose, site, function and operation concept of a berthing facility. Standard fender design practice to date uses a nominal berthing energy specified in terms of the displacement, approach speed and attitude of docking ship. This paper describes the result of analysis of berthing and mooring system and selection of safe facility (fender and anchor) for waterway. The study determines the safe berthing velocity, berthing energy and environmental loading for ships at various displacements [98,99].

Methodology

Berthing facility structure and barge particulars

Platform which is originated as a barge is design because it is a moveable and floating structure which can be use anywhere and can be installed in anytime when needed. D-type fender and Tee bollard are selected to use as the protection equipments for the barge. Figure 102, Table 48 shows process for berth. Figure 103 shows the process of for mooring system design.

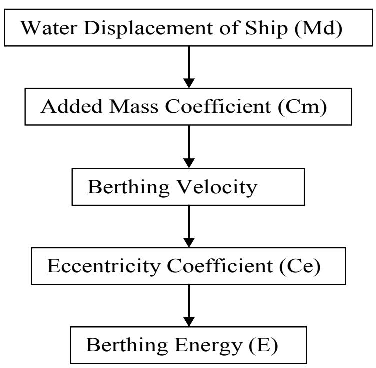


Figure 102: Flow chart of determine the Berthing Energy (E).

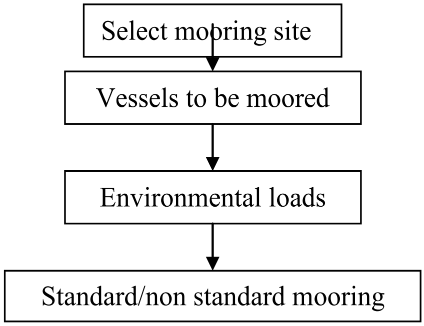


Figure 103: Mooring design process.

Particular	Unit
LOA	67.3 m
Breadth	18.3 m
Moulded depth	3.7 m
Depth	2.68 m
Lightship	383 tons
Maximum Displacement	2380 tons
Maximum Draft	2.9 m
Capacity	2500 tons
Wetted Surface Area	1212.98 m^2
Volume	2198.24 m^3

Table 48: Barge particulars.

Berthing energy and berthing velocity: The berthing energy is used to determine the most suitable fender for the berthing facilities. The ships ranging from 1000-10000 tons in water displacement are choosing as models of ships that berth at the facilities. As the ship is stopped by the fender, the momentum of the entrained water continues to push against the ship and this effectively increases its overall mass. The mass of specified water is called Added Seawater Mass; the added sea-water influence coefficient is called Cm [100,101].

Water displacement of ship: The ships ranging from 1000-10000tons in water displacement for this analysis.

Added mass coefficient: Empirical formula for the added mass coefficient (Cm) is given as:

$$Cm = 1 + \frac{\Pi D^2 L\rho}{4Md} \tag{1}$$

Where, Cm = Added Mass Coefficient, D = Draft (m), L = Ship Length (m), P = Seawater Density (t/m^3), Md = Wate Displacement of ship.

Berthing velocity: Empirical formula used for berthing speed (m/sec)

$$v = \frac{1\frac{1}{\log\left(M_s\right)}}{\sqrt[3]{Ms/1000}} \tag{2}$$

Where, v = Berthing Speed (m/sec), M_S = Loaded Water Displacement of the ship (tons)

Eccentricity coefficient: Empirical formula for the Eccentricity Coefficient (Ce)

$$Ce = \frac{1}{1+\left(I/r^2\right)} \tag{3}$$

Where: r = Gyration radius of ship against axial of enter of gravity on horizontal plane.I =Project of the distance between the center of gravity and berthing point on dock direction.

Berthing energy: The impacting energy calculation is subject to the ships berthing method which can be defined as following:

Ship-To-Ship Berthing energy empirical formula

$$E = 0.5\left[\frac{\left(Md_1 \times Cm_1\right)\times\left(Md_2 \times Cm_1\right)}{\left(Md_1 \times Cm_1\right)+\left(Md_2 \times Cm_1\right)}\right]\times V^2 \times Ce \tag{4}$$

Where, E is Vessel effective berthing energy (ton.m), Md-Displacement Tonnage (ton), V-Berthing Velocity (m/s), Cm Added Mass Coefficient, Ce-Eccentricity Coefficient

The berthing velocity is obtained from actual measurements or relevant existing statistic information. When the actual measured speed velocity is not available, the BSI and PIANC etc. standard is adopted to determine the required velocity value [102,103]. The berthing energy is obtained from:

$$Cm = 1+\frac{\pi D^2 L\rho}{4Md} \tag{5}$$

$$E = 0.5\left[\frac{\left(Md_1 \times Cm_1\right)\times\left(Md_2 \times Cm_1\right)}{\left(Md_1 \times Cm_1\right)+\left(Md_2 \times Cm_1\right)}\right]\times V^2 \times Ce \tag{6}$$

$$Ce = \frac{1}{1+\left(\frac{I}{r^2}\right)} \tag{7}$$

Where, E-Vessel effective berthing energy (ton.m), Md-Displacement Tonnage (ton), V-Berthing Velocity (m/s), Cm Added Mass Coefficient, Ce-Eccentricity Coefficient. Berthing velocity is obtained

$$v = \frac{1-\frac{1}{\log\left(Ms\right)}}{�\left(\frac{Ms}{1000}\right)} \tag{8}$$

Where, v = Berthing Speed (m/sec), M_S = Loaded Water Displacement of the ship (tons)

Environmental loads on berthing facilities: Moorings are classified as either fleet moorings or fixed moorings. A fleet mooring consists of structural elements, temporarily fixed in position, to which a vessel is moored. These structural elements include anchors, ground legs, a riser chain, a buoy and other mooring hardware. Lines and appurtenances provided by vessels are not a part of the fleet mooring. Loads on moored vessels are due to wind result primarily from drag. Eenvironmental loads which are winds, currents and waves produce loads on moored vessels are considered. Static wind and current loads are discussed in detail below. Static loads due to wind and current are separated into longitudinal load, lateral load, and yaw moment. Flow mechanisms which influence these loads include friction drag, form drag, circulation forces, and proximity effects. The mooring analysis is described in the flowing section [104,105].

Lateral wind load: Lateral wind load on barge is determined using the following:

$$F_{yw} = \frac{1}{2}\rho_a V_w^2 A_y C_{DW} sin\theta_w \tag{9}$$

Where: F_{yw} = lateral wind load, in pounds, P_a = mass density of air = 0.00237 slugs per cubic foot at 68°F, V_w = wind velocity, in feet per second, A_Y = lateral projected area of barge, in square feet, C_{DW} = wind-force drag coefficient, θ_W = wind angle

Longitudinal wind load: Longitudinal wind load on barge is determined using following:

$$F_{xw} = -\frac{1}{2}\rho_a V_w^2 A_x C_{DW} cos\theta_w \tag{10}$$

Where: F_{xw} = Longitudinal wind load, in pounds, P_a = Mass density of air = 0.00237 slugs per cubic foot at 68°F, V_w = Wind velocity, in feet per second, A_x = Longitudinal projected area of barge, in square feet, C_{DW} = Wind-force drag coefficient

Wind Yaw Moment: Wind yaw moment is computed using the following:

$$M_{xyw} = F_{yw} e_w \tag{11}$$

Where: M_{xyw} = wind yaw moment, in foot-pounds, F_{yw} = lateral wind load, in pounds, e_w = eccentricity of F_{xw}, in feet.

$$e_w = L\left[\frac{3.125}{100} - 0.0014\left(\theta_w - 90°\right)\right] \text{for } 0 \le \theta_W \le 180°, \tag{12}$$

$$e_w = L\left[\frac{3.125}{100} - 0.0014\left(\theta_w - 270°\right)\right] \text{for } 180° < \theta_W \le 360° \tag{13}$$

L= length of barge

Current loads developed on moored vessels result from form drag, friction drag, and propeller drag. Lateral forces are dominated by form drag. Form drag is dependent upon the ratio of vessel draft to water depth: as the water depth decreases, current flows around rather than underneath the vessel. Longitudinal forces due to current are caused by form drag, friction drag, and propeller drag.

Lateral current load: Current loads developed on moored vessels result from form drag, friction drag, and propeller drag. Lateral forces are dominated by form drag. Form drag is dependent upon the ratio of vessel draft to water depth: as the water depth decreases, current flows around rather than underneath the vessel. Lateral current load is determined from the following equation:

$$F_{yc} = \frac{1}{2}\rho_w V_c^2 L_{wL} T C_{yc} sin\theta_c \tag{14}$$

Where: Fyc = lateral current load, in pounds, P_w = mass density of water = 2 slugs per cubic foot for sea water, V_c = current velocity, in feet per second, L_{wL} = vessel waterline length, in feet, T = vessel draft, in feet,Cyc = lateral current-force drag coefficient, θ = current angle

The lateral current-force drag coefficient is given by:

$$C_y c = C_y c \mid oo ?+ (C_y c ? \mid 1 - ? C_y c ? \mid oo ?) e^{(-k(} wd / T - 1)) \tag{15}$$

Where: C_{yc} = Lateral current-force drag coefficient,C_{yc}100 = Limiting value of lateral current-force drag coefficient for large values, of Wd/T, C_{yc}/1 = Limiting value of lateral, Current-force drag coefficient for Wd/T = 1, e = 2.718, k = Coefficient, wd = Water depth, in feet, T = Vessel draft, in feet

Longitudinal current load: Longitudinal forces due to current are caused by form drag, friction drag, and propeller drag [100,106]. Longitudinal current load procedures. Longitudinal current load is determined using the following equation:

$$F_{xc} = F_{x\ form} + F_{x\ fricion} + F_{x\ prop} \quad (16)$$

Where: F_{xc}=Total longitudinal current load, F_{xform} =Longitudinal current load due to form drag, $F_{x\ friction}$ =Longitudinal current load due to skin friction drag, $F_{x\ prop}$=Longitudinal current load due to propeller drag, Form drag is given by the following equation:

$$F_{x\ form} = -\frac{1}{2}\rho_w V_c^2 BTC_{xcb} cos\theta_c \quad (17)$$

Where: F_{xform} = Longitudinal current load due to form drag, P_w = Mass density of water = 2 slugs per cubic foot for sea water, V_c = Average current speed, in feet per second, B = Vessel beam, in feet, T = Vessel draft, in feet, C_{xcb} = Longitudinal current form-drag coefficient = 0.1, θ = Current angle.

Skin friction drag is given by the following equation:

$$F_{x\ fricion} = -\frac{1}{2}\rho_w V_c^2 SC_{xca} cos\theta_c \quad (18)$$

Where: $F_{x\ friction}$ = Longitudinal current load due to skin friction, P_w = Mass density of water = 2 slugs per cubic feet for sea water, V_c = Average current speed, in feet per second, Wetted surface area, in square feet.

$$\left(1.7TL_{WL}\right) + \left(\frac{35D}{T}\right) \quad (19)$$

T = Vessel draft, in feet, L_{wL} = Waterline length of vessel, in feet, D = Displacement of ship, in long tons, C_{xca} = Longitudinal skin-friction coefficient

$$\frac{0.075}{\left(logR_n - 2\right)^2} \quad (20)$$

R_n = Reynolds number = V L_{wLc} cos θ_c/γ, γ = Kinematic viscosity of water ($1.4x10^{-5}$ square feet per second), θ_c= Current angle

Current yaw moment: Current Yaw moment procedure for determining current yaw moment. Environmental loading data considered is given in Table 49. Current yaw moment is determined using the following equation:

$$M_{xyc} = F_{yc}\left(\frac{e_c}{L_{WL}}\right)LWL \quad (21)$$

Where: M_{xyc} = Current yaw moment, in foot-pounds, F_{yc} = Lateral current load, in pounds, $\left(\frac{e_c}{L_{WL}}\right)$ = Ratio of eccentricity of lateral current load measured along the longitudinal axis of the vessel from amidships to vessel waterline length, e_c = Eccentricity of F_{yc}, L_{wL} = Vessel waterline length, in feet. The value of $\left(\frac{e_c}{L_{WL}}\right)$ is given as a function of current angle, θ_c and vessel type.

Environmental Consideration	
Wind	Normal wind speed = 8m/sec Extreme wind speed = 10.7m/sec
Waves	Max wave height = 0.5m(for 10.7m/sec)
Current	Slight change 1-1.2m/sec
Average water depth	6 m

Table 49: Environmental parameters.

Winds, currents and waves produce dynamic loads on moored vessels due to waves follows. Static loads due to wind and current are separated into longitudinal load, lateral load and yaw moment. The following relations are used to determine the wind and waves loads [100,107].

$$F_{yw} = \frac{1}{2}\rho_a V_w^2 A_y C_{DW} sin\theta_w \quad (22)$$

$$F_{yw} = \frac{1}{2}\rho_a V_w^2 A_y C_{DW} \cos\theta_w \quad (23)$$

Result and Discussion

Physical system parameters: General arrangement of for mobile berthing facilities is designed based on specification:

Vessel-Length of vessel (Length overall 76.2 m (L), Beam (B) 21.3 m, Draft (D) 4.0 m),

Waterway-(Depth 6 m, Width 3 B, UKC 40%)

Berthing energy: Berthing velocity for the ships displacement range of 1000 tons to 10000 tons of water displacement is considered. The highest speed value of the berthing velocity occur when the 1000tons displacement ship berthing at the berthing facilities which is 0.6667m/sec, the higher the value of water displacement of the ship, the lower value of berthing velocity.0.653knot is considered best operating speed for vessel of 2000tons and 0.5267 knot is considered optimal speed for vessel of 5000 tons (Figure 104).

Considering ships of 1000 to 10000 tons displacement, the optimal berthing energy for the 2000 tons displacement ship berthing is 104.1ton.m and for 5000 is 94.2 Tons (Figure 105). Figure 106 shows PIANC acceptability criteria, where a. Easy berthing (sheltered) b.dificult berthing (berthing) c. easy berthing (exposed, d. Good berthing (exposed), Difficult berthing (exposed).

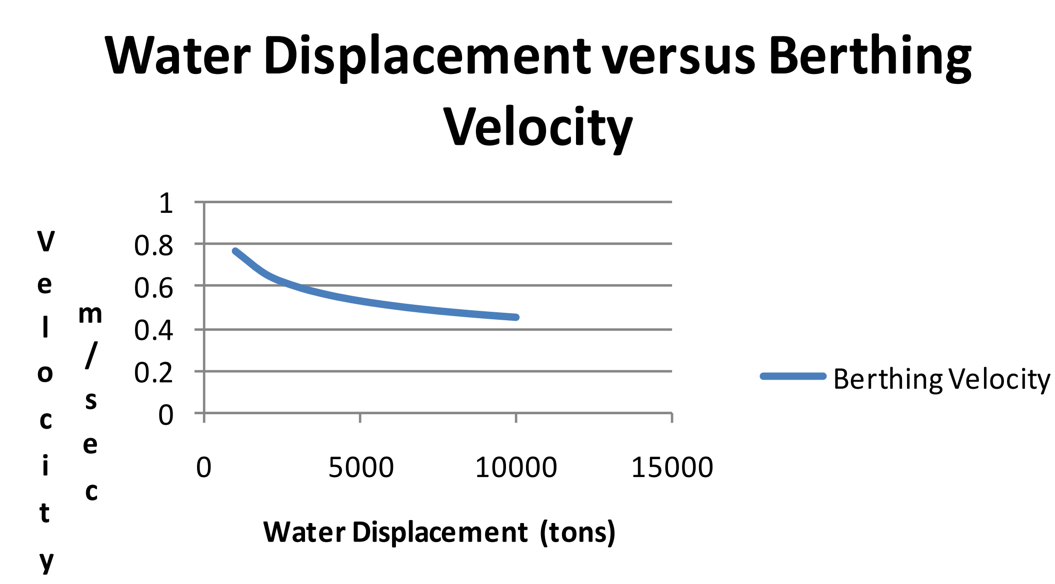


Figure 104: Graph water displacement versus berthing velocity.

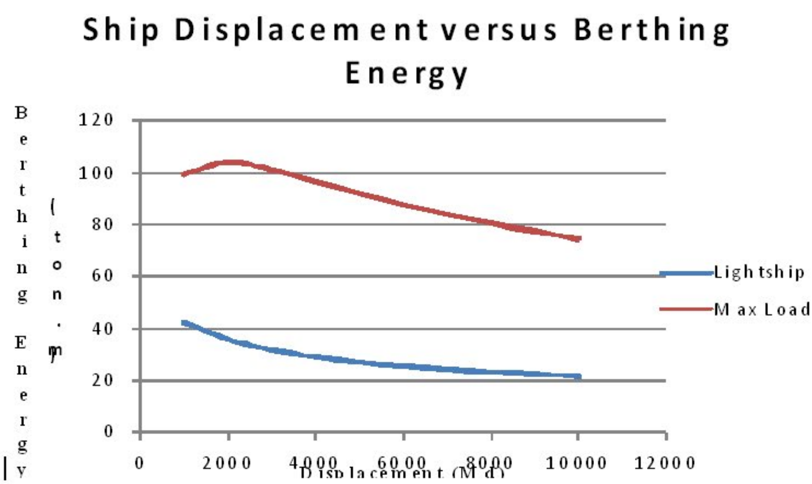


Figure 105: Graph water displacement versus berthing velocity.

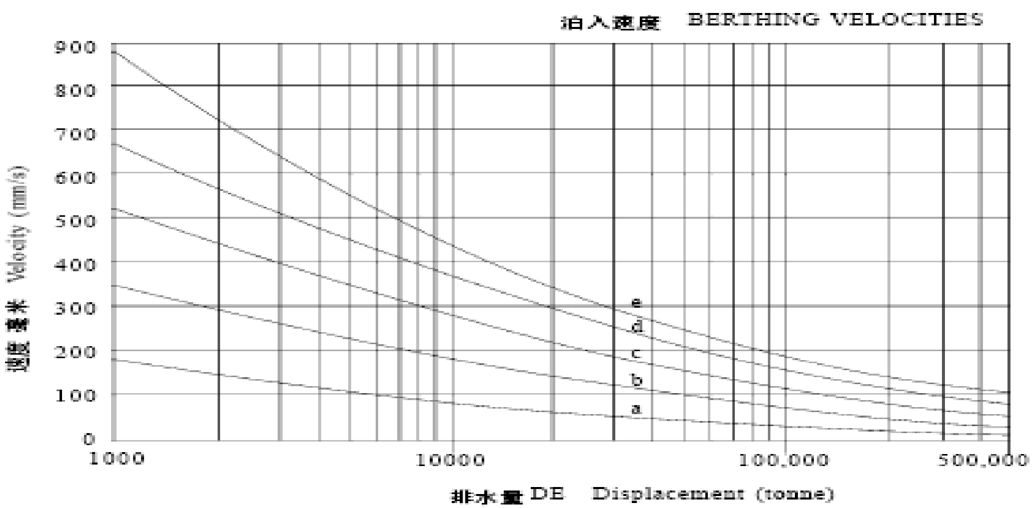


Figure 106: PIANC Standard for berthing velocity.

The wind angle is taken from 30°c to 175°c with the average 30°c as interval. The maximum lateral wind load occurs when the wind is extreme at 90°c which has the value of 3109.75pounds. The maximum longitudinal wind load occurs when the wind is extreme at 175°c which has the value of 1500.52 pounds. Figure 107 can be considerably acceptable as the amount may have little impact in the vessel dynamic positioning. The current angle is taken from 30°c to 175°c with the average 30°c as interval. The maximum lateral current load occurs at the berthing maximum draft and current angle of 90°c which has the value of 112.34pounds. The maximum longitudinal current load occurs at berthing minimum draft and current angle of 145°c which has the value of 12.21pounds (Figure 108).

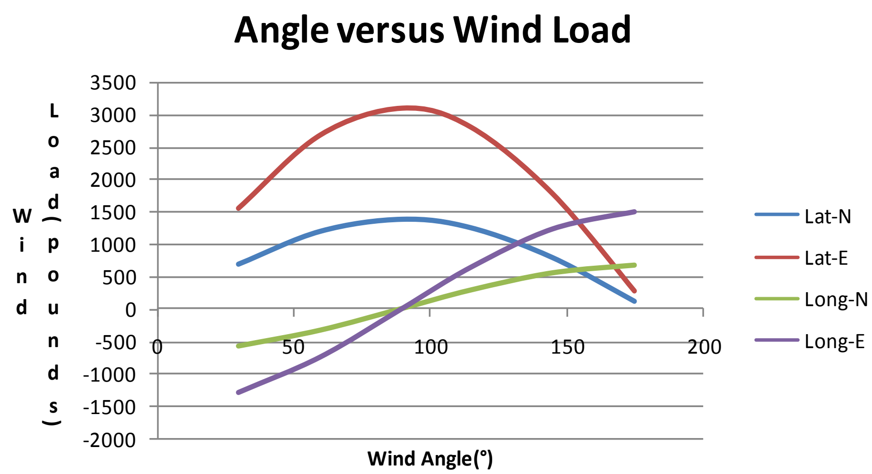


Figure 107: Wind angle versus wind load.

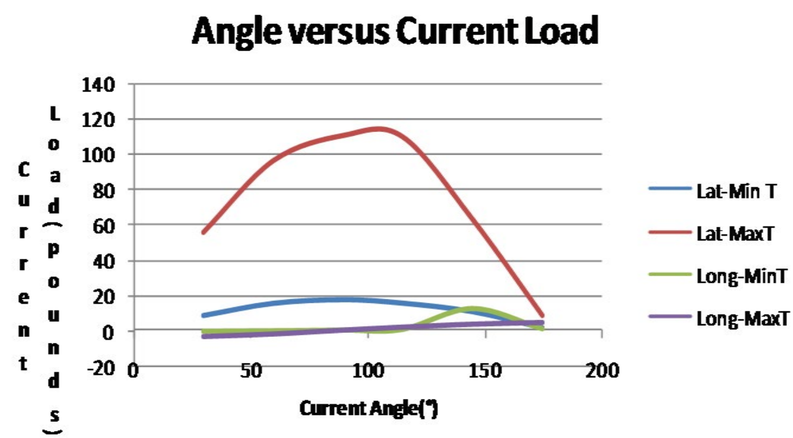


Figure 108: Current angle versus current load.

Mooring and berthing facilities selection: Design of mooring components

Total Lateral load on berthing facilities

= Total lateral wind load + total lateral current load

= 3109.75 pounds + 113.24 pounds = 3222.09 pounds

Total longitudinal load on berthing facilities

= Total longitudinal wind load + total longitudinal current load

= 1500.53 pounds + 12.53 pounds = 1513.06 pounds

The horizontal hawser load using the following equation:

$$H = \sqrt{F_{xT}^{\ 2} + F_{yT}^{\ 2}}$$

$$H = \sqrt{1513.06^2 + ?3222.09^2} = 3559.66\, pounds$$

Where: H = horizontal hawser load, FxT = total longitudinal load, FyT = total lateral load

Chain selection: Approximate chain tension, T = 1.12 H (Horizontal Hawser Load) = 3986.66 pounds

Maximum allowable working load, Tbreak

Tdesign = 0.35 Tbreak

3986.66 pounds = 0.35 Tbreak

Tbreak = 11390.46 pounds

*1-inch chain with a breaking strength of 14,500 pounds

Anchor selection: Most fleet moorings use either a Stockless or a Stato anchor because there is considerable Navy experience with these anchor types, they are currently in large supply and they have been tested extensively. Furthermore, Stockless and Stato anchors can be used to satisfy the required capacity of the standard fleet moorings for most conditions. Parameter in determine the type of anchor chain is as followed [108,109].

Holding capacity = efficiency x weight

3559.52 = (4) (weight)

Weight = 3559.66/4 =889.92pounds /0.9 kips

1,000-pound (1-kip) Stockless anchor can be selecteed

Total Lateral load on berthing facilities is 3222.09 pounds, the total longitudinal load on berthing facilities is 1512.73 pounds and the horizontal hawser load, H is 3559.52 pounds.

Fender selection: According to the British standard, the ultimate fender capacity is 2 X berthing Energy. The maximum berthing energy occurs when the berthing facilities are in the maximum load and the berthing ship is at 1000 tons displacement which has the value of 89 ton.m. The fender capacity must be at least 2 x 89 ton.m = 178 ton.m.

Conclusion

This paper presents analysis of safe mooring and berthing as well as selection of safe berthing and protection navigation structure (anchor and fender) require for protection of the facilities. The berthing facilities can help to improve safety, contribute to subsystem analysis that reduces uncertainty risk in waterway. The heavy seaborne traffic and the cost of building an extra Jetty which may become a burden to ports operator can also be offset with information deduce from the study. Mobile berthing facilities can be installed anytime and anywhere to help the port operator to save money and time. The analysis can be improved as a working platform by simulation and prototyping for experiment that can be used for further investigation.

10. CFD Simulation for Cavitation Studies and Optimization of Propeller Blade

Abstract

Propeller cavitation is a major problem in ship operation and the costs of repair and maintenance is high for ship-owner.Proper design of propeller plays a very important role in life cycle and the performance of vessel. The use of simulation to observe various

parameters that affect cavitations can be helpful to optimize propeller performance. This project design and simulates cavitations flow of a Kaplan series, Fixed Pitch Propeller (FPP) of a 48 meters Multipurpose Deck Ship at 11 knots. Simulation test was carried out for laminar and turbulent flow using Computational Fluid Dynamics (CFD) approach to observe cavitations occurrence at selected radius (300 rpm and 600 rpm). The parameters consider are pitch angle, angle of attack, viscosity of sea water, operating vapour pressure in the seawater, engine power, lift and drag vectors of each of the blade sections and resultant velocity of the fluid flow.Comparison of performance is made and it compares well with the theory. Thrust coefficient (K_T), torque coefficient (K_Q), thrust (T), advance coefficient (J) and cavitations number (σ), was calculated to deduce efficiency and validate the model. The study can be use to build prototype physical model that could be beneficial for future additional experimentation investigation.

Keywords: Simulation, cavitation, optimization, performance, propeller

Introduction

Marine propeller is a propulsion system which turns the power delivered by the engine into thrust to drive the vessel through water. Propeller cavitation is a general problem encountered by the ship owner, whereby it causes vibrations, noises, degradation of propeller performance, deceases engine efficiencies, effects the life cycle of the ship and also resulted in high cost of maintenance.

The basic physics of cavitation occurs when the pressure of liquid is lower or equal to the vapour pressure, which depends on the temperature thus forming cavities or bubbles. The compression of pressure surrounding the cavities would break the cavities into smaller parts and this increases the temperature. Collapse of bubbles if contact with parts of the propeller blades will create high localized forces that subsequently erode the surface of the blades.

Simulation on cavitating flow using CFD can be carried out to determine the performance of the propeller. A model is generated in Gambit and fluid flow physics are apply to predict the fluid dynamics and other physical phenomena related to propeller[110]. Stated that, CFD can provide potential flow analysis such as flow velocities and pressure at every point in the problem domain as well as the inclusion of viscous effects.

Previous studies on propeller cavitation: [111] in their studies, generated hybrid grid of about 187 000 cells using Gambit and TGrid.The blade surface was firstly meshed with triangles including the root, tip and blade edges. The turbulent boundary layer was resolved with four layers of prismatic cells between blade and hub surfaces. In the cavitating propeller case, the boundary conditions were set to simulate the flow around a rotating propeller in open water. Inlet boundary, velocity components for uniform stream, blade and hub surfaces, and outer boundary were included.This ensured the rotational periodicity of the propeller on the exit boundary by setting the pressure corresponding to the given cavitation number and other variables was later extrapolated [112,113].

On the other hand [112] applied a mixture models with algebraic slip to simulate cavitating flow over a NACA 66 hydrofoil. This multiphase flow model which is incompressible fluids consists of liquid and vapour was used as primary and secondary phase respectively. Structured quadrilateral grids of 19 490 cells were meshed.Inflow and outflow boundary were indicated as velocity magnitude and direction and zero gauge pressure respectively. Contour of vapour volume fraction shown in Figure 109 indicates that cavity can be observed at the mid-chord region [114,115].

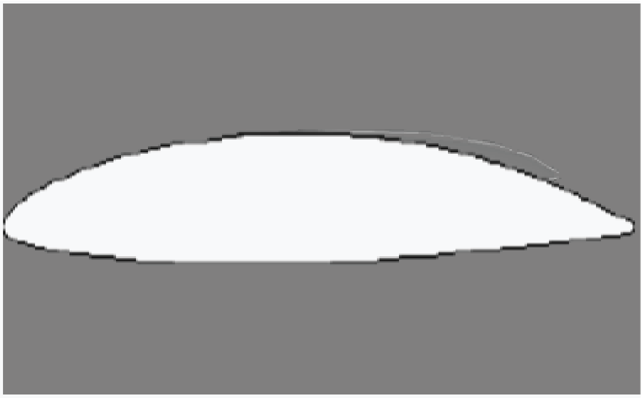


Figure 109: Cavity at the mid-chord region.

This study is focused mainly on simulating a cavitating flow at the propeller blade section of Kaplan series order to optimize the propeller blade to increase its performance. Two-dimensional simulations of different radius were carried out at different revolution per minute (rpm) and the results were compared based on the pressure difference. The objective is to simulate and investigate the water flow at the propeller blade section and to recommend measure to reduce cavitation in order to increase its efficiencies [114,116].

Methodology

Model generation in gambit

The Propeller Blade models of 0.2R and 0.6R were generated and computational domains were created to assume water is flowing from far towards the Propeller Blade. Figure 109 and Table 50 show far field boundary conditions surrounding the Propeller Blade. Then, meshing was carried out between the boundaries and Propeller Blade to determine the accuracy of the model generation. Figure 110 and 111 show the meshing process [117,118,119].

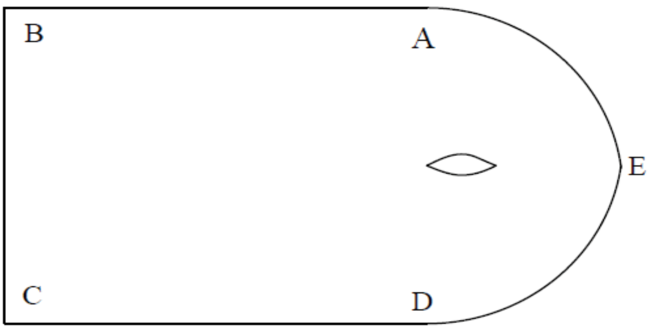


Figure 110: Creation of far field boundaries to simulate the fluid behaviour in Fluent.

Curve	Boundary condition
AED	Far field 1
AB	Far field 2
CD	Far field 2
BC	Far field 3

Table 50: Boundary conditions for simulating fluid behaviour.

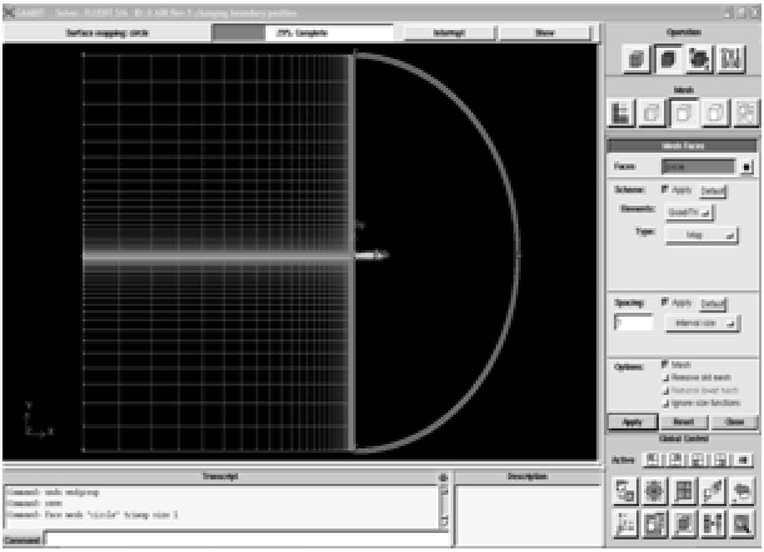


Figure 111: Meshing process of 0.2R Propeller Blade section.

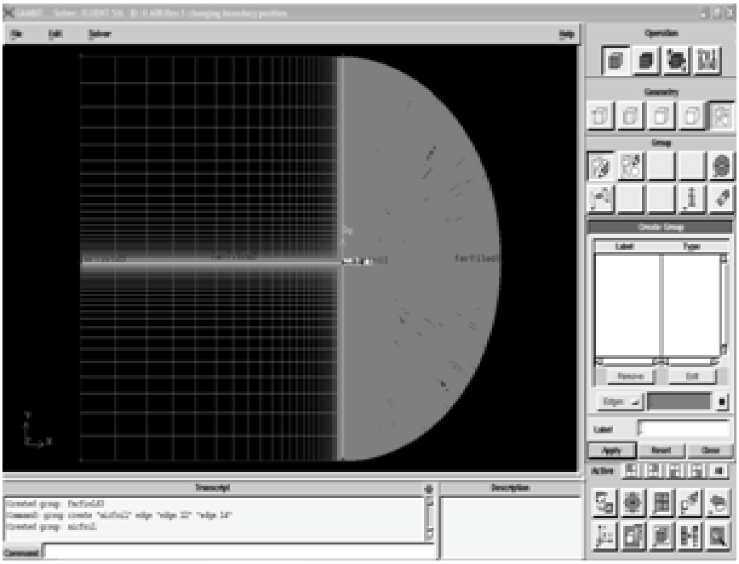


Figure 112: Meshing result of 0.2R Propeller Blade section with boundaries creation.

Numerical method: The Propeller Blade of 0.2R and 0.6R were simulated in Fluent 6.3.26. Pressure based numerical solver, laminar and turbulent physical model were selected as the functioning base for 300rpm and 600rpm. Then, the material properties for instance and the density of sea water and viscosity value were defined and calculated. Consequently, the operating condition was set to be 2296 Pa, which is the condition for vapour pressure at sea, water when the temperature is 20°C. On the other hand, the boundary conditions of far field 1 and far field 2 were specified as velocity inlet, where by the velocity magnitude and direction was calculated [120,121].

As for far field 3, this boundary was specifies as pressure outlet, the gauge pressure was set to be 0 Pa. The existence of inflow and outflow boundaries enables the characteristics of fluid to be observed by entering and leaving the flow domain. The turbulent viscosity ratio was set to correspond to the default value for 600 rpm of both radiuses. Next, the solution procedure was set as simple algorithm, and under discretization, the pressure and momentum were set as Standard and First Order upwind respectively [122,123].

Results and Discussions

Three Propeller Blade section profiles at different radius, such as 0.2R, 0.6R and 1.0R were simulated. The CFD results were then, visualized and analyzed for comparison.

Result of 0.2R propeller blade section: The CFD results, for instance, three residuals of CFD calculation lift and drag force, velocity vector plot, and contour plot were visualized and analyzed.

Iteration 0.2R: Figure 112 shows 250 iteration results, whereby the continuity; x-velocity and y-velocity were calculated for flow equation.

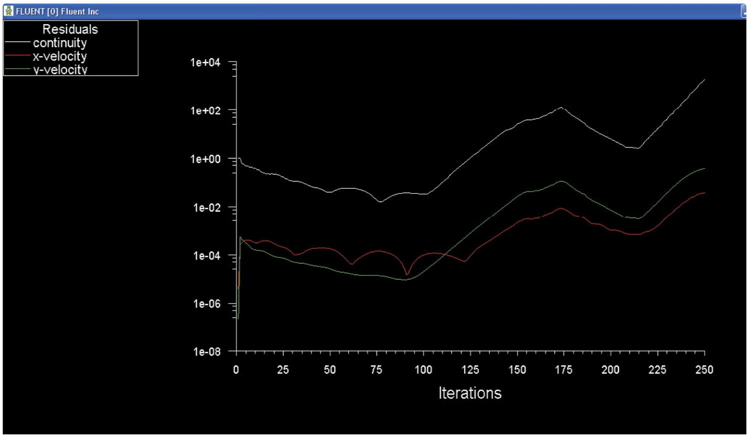


Figure 113: Iteration results of three residuals.

Based on Figure 113, it can be seen that the residuals were moving upwards and not fulfilling the converging criteria, that is to be below 0.001. This shows that the solution was diverging instead of converging. As for the lift and drag vector force, Figure 113 and 114 shows a divergence result which is not compatible with the convergence criteria.

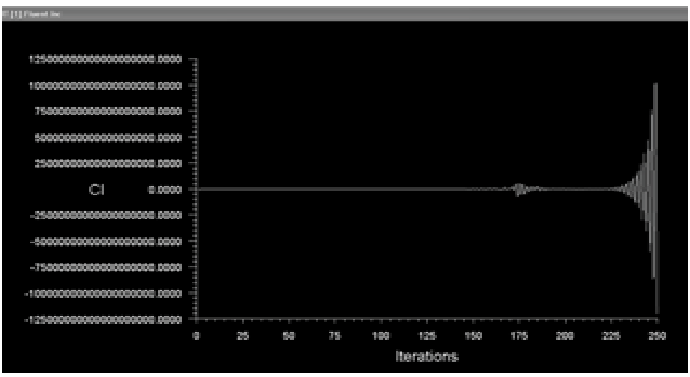


Figure 114: Lift vector force iterated by CFD solver.

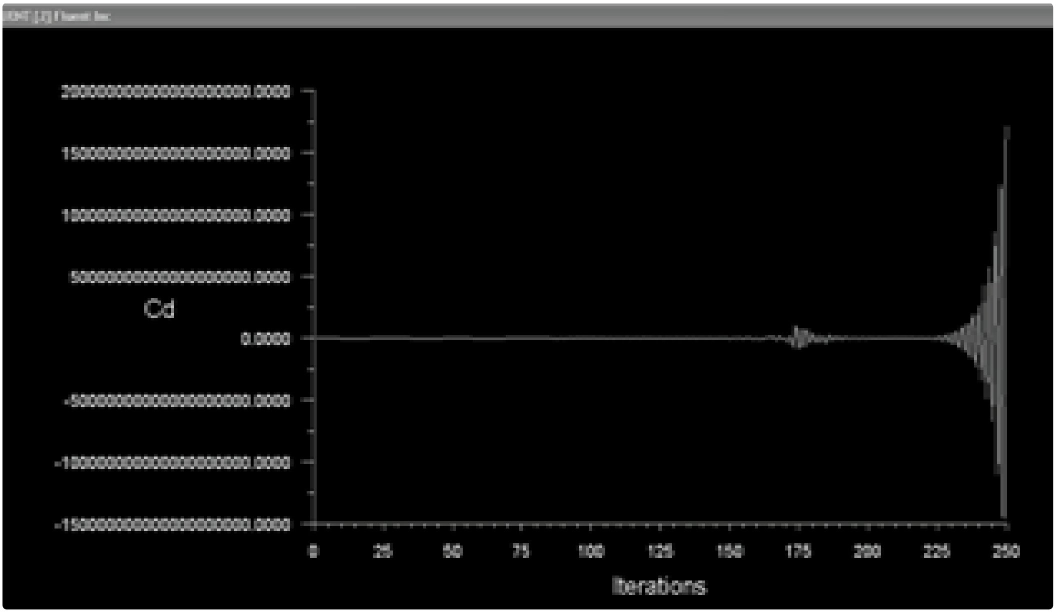


Figure 115: Drag vector force iterated by CFD solver.

Contours of velocity vectors: Laminar flow of 0.2R Propeller Blade section at 300 rpm is observable in Figure 115 and 116. There is no pressure gradient observed surrounding the Propeller Blade section. This indicates that the possibility of cavitation to occur is very small.

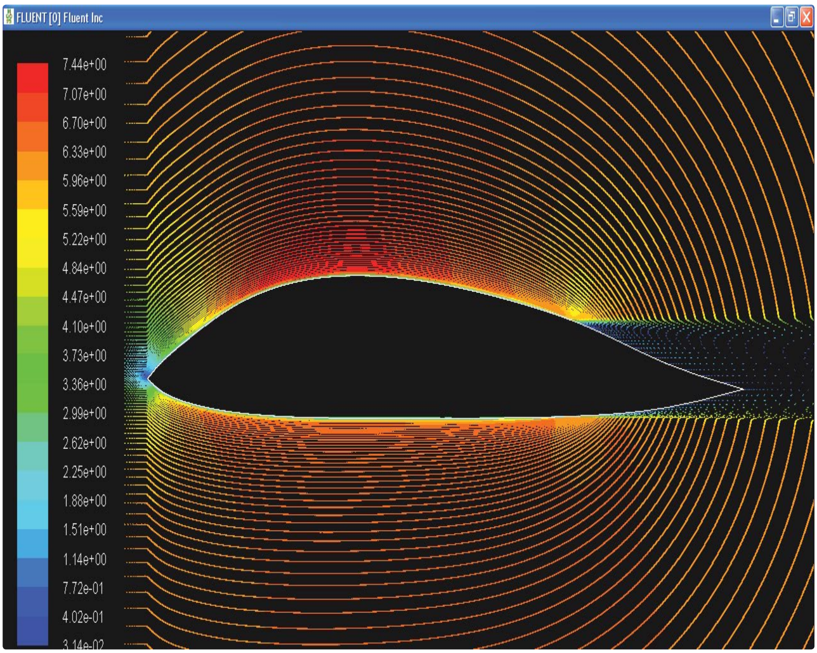


Figure 116: Contour of velocity vector of 0.2R at 300rpm and 600rpm.

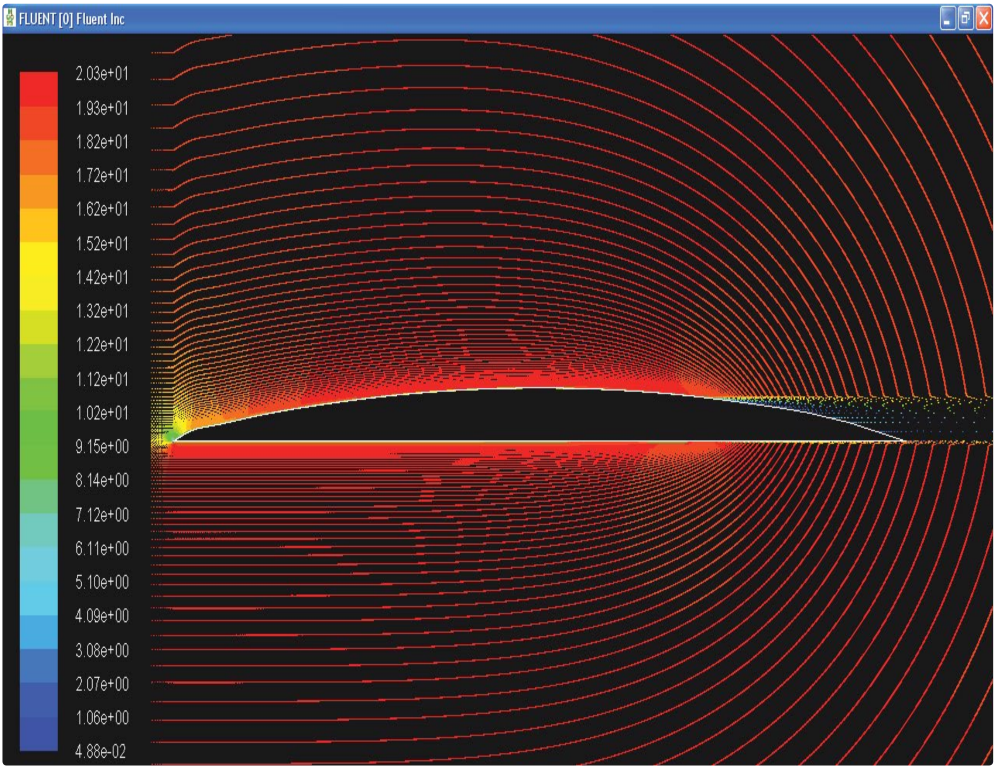


Figure 117: Low velocity vector of 0.6R at leading and trailing edge at 300 rpm and 600 rpm.

Contours of absolute pressure: Laminar flow of 0.2R Propeller Blade section at 300 rpm is observable in Figure 117. There is no pressure gradient observed surrounding the Propeller Blade section. This indicates that the possibility of cavitation to occur is very small.

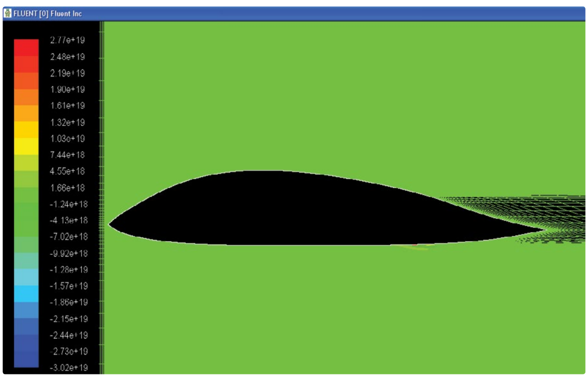


Figure 118: No pressure gradient which indicated no cavitation occurrence at 300rpm.

Turbulent flow at 600 rpm shows pressure difference in Figure 118. Lowest pressure is observed below the Propeller Blade section. This indicates that possibility of cavitation to occur is high.

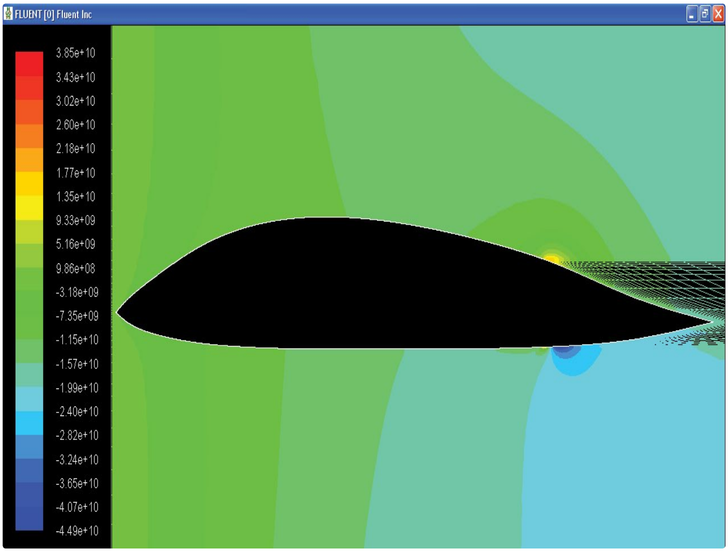


Figure 119: Lowest pressure is observed below 0.2R Propeller Blade section.

Result of 0.6R propeller blade section: For 0.6R Propeller Blade section, the CFD results, for instance, three residuals of CFD calculation, lift and drag force, velocity vector plot and contour plot were visualized and analyzed.

Iteration of 0.6R

Figure 119 shows 250 iteration results, whereby the continuity; x-velocity and y-velocity were calculated for flow equation. It can be seen that the residuals were moving downwards equivalent to the convergence criteria, which is 0.001. This shows that the solution was converging.

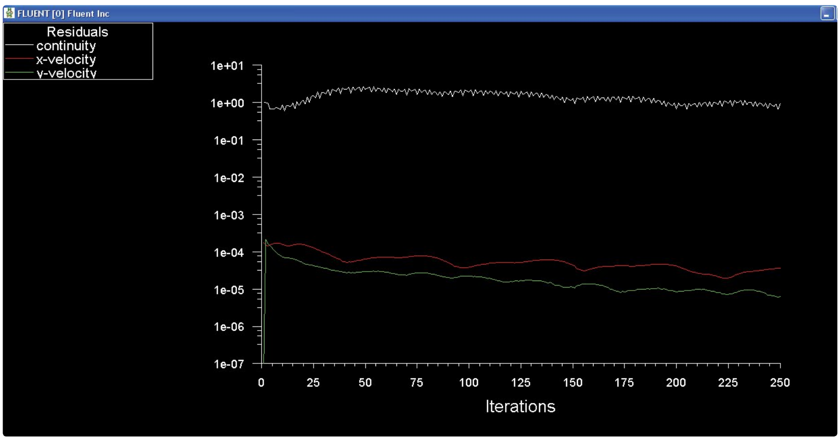


Figure 120: Iteration results for continuity, x-velocity and y-velocity.

Lift and drag vector force as shown in Figure 120 and 121 shows a convergence solution through the lift and drag convergence history.

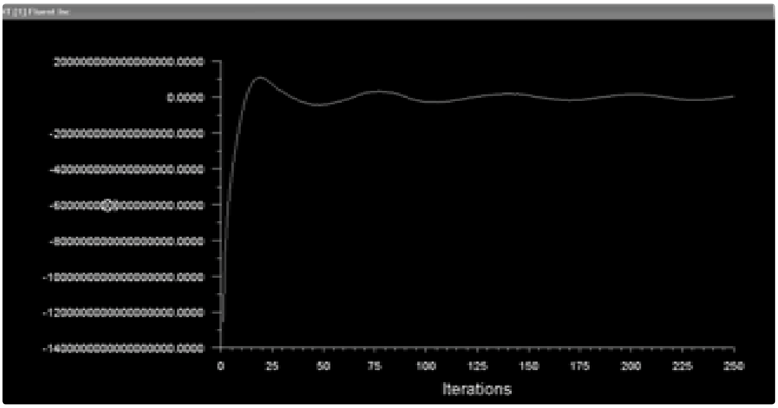


Figure 121: Monitoring the solution convergence through lift convergence history.

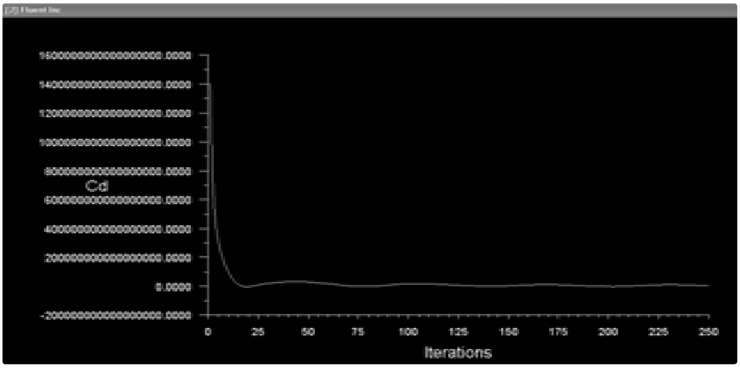


Figure 122: Monitoring solution convergence through drag convergence history.

On the other hand, laminar flow simulation of 0.6R at 300 rpm resulted in lower pressure observable at the trailing edge as shown in Figure 122.

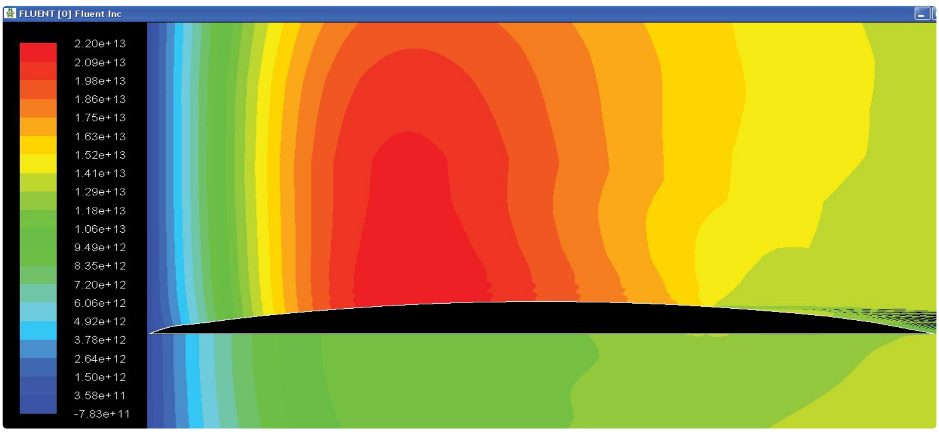


Figure 123: Lower pressure at trailing edge of 0.6R.

Besides, turbulent flow for 0.6R of 300 rpm is seen that cavitation occurred at the upper surface of the Propeller Blade section as shown in Figure 123.

Figure 124: Low pressure is spotted at the upper surface of the Propeller Blade section.

For the 600 rpm, huge area of lower pressure is observed at the upper surface of the 0.6R Propeller Blade section of the turbulent flow as shown in Figure 124.

Figure 125: Huge area of lower pressure is observed at the upper surface.

Based on the above contours, cavitations can happen if the Propeller Blade radius section increases, especially for 0.6R compare to 0.2R. This is because, the bigger the radius, much pressure would be concentrated at that location. Besides this, in the turbulent flow, cavitation is more likely to induce compare to laminar flow due to its fluid characteristics. Also, the higher the rpm, the lower the absolute pressure.

Graph of absolute pressure versus curve length: The graph in Figure 125 shows that, the pressure decreases when it pass by the Propeller Blade which equivalent to the diagrams shown above and as it leave the Propeller Blade, the pressure slowly increases back to its actual pressure.

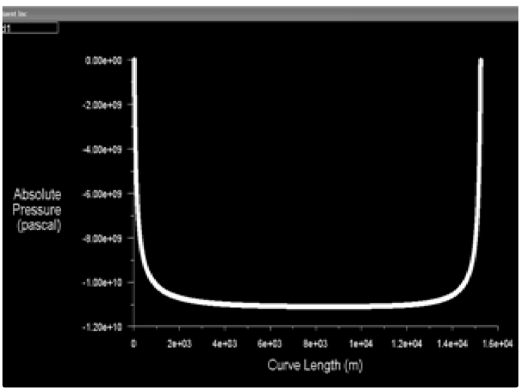


Figure 126: Absolute pressure characteristic moving across a Propeller Blade.

Figure 126 shows cavitation number, σ versus advance coefficient, based on the graph. When the propeller rotates at 300 rpm, the operating condition falls in the region for conventional propeller, which is suitable for most of the merchant vessels, whereas, at 600 rpm, propeller operating condition falls in the poor region for high speed propeller operation. This indicates low efficiency for propeller since low advance coefficient implies high propeller power coefficient. This is probably due to inaccurate application of propeller rotational speed with engine load and gear box used.

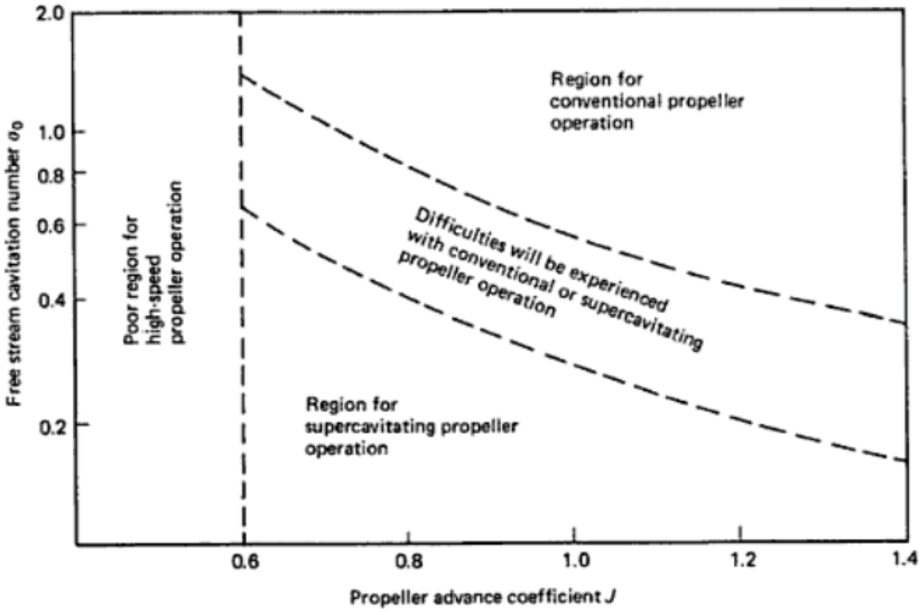


Figure 127: Cavitation number, σ versus advance coefficient.

When the propeller rotates at 300 rpm, the advance coefficient and cavitation number reaches the region for conventional propeller operation. This means that at 300 rpm, the propeller rotates at a good condition suitable to the engine load and gear box required. On the other hand, when the propeller rotates at higher speed, it reaches at the poor region for high speed propeller operation which indicates damages, vibration and cavitation would occur. Based on the results of velocity and contour plots of 300 rpm and 600 rpm, the higher the rpm, the lower the absolute pressure, which is the condition for cavitation to occur. This is caused by high rotational rates of the propeller which creates high and low pressure region on the blades. Besides, when the radius increases along the propeller, cavitation might happen too. Airfoil section profile at 0.2R does not have cavitation due to less pressure concentration in that region compare to 0.6R airfoil section profile. At 0.6R airfoil section profile, more works are required to be done in that region.

Conclusion

The paper presents the result of water flow at the blade section profile. Cavitation occurrence is observed to be at the upper surface of 0.6R compare to 0.2R of Propeller Blade section due to different pressure concentration. Besides, cavitation is predicted at low absolute pressure when the rpm is high and this correlate with theory hypothesis. Optimization of the propeller can be achieved by increasing the Blade Area Ratio (BAR) and compare it with the standard Kaplan BAR value that is, 0.85. The result deduce from this study can be added to existing databased for validation purposes especially for ship navigating with the Malaysia water. This could provide information on environmental differential impact on propeller. It is recommended that further multiphase, experimental simulation should carry out to test rotational speed of propeller at different power produced by the engine load.

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